Nanotechnology for water treatment and desalination

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Concerns in water crisis

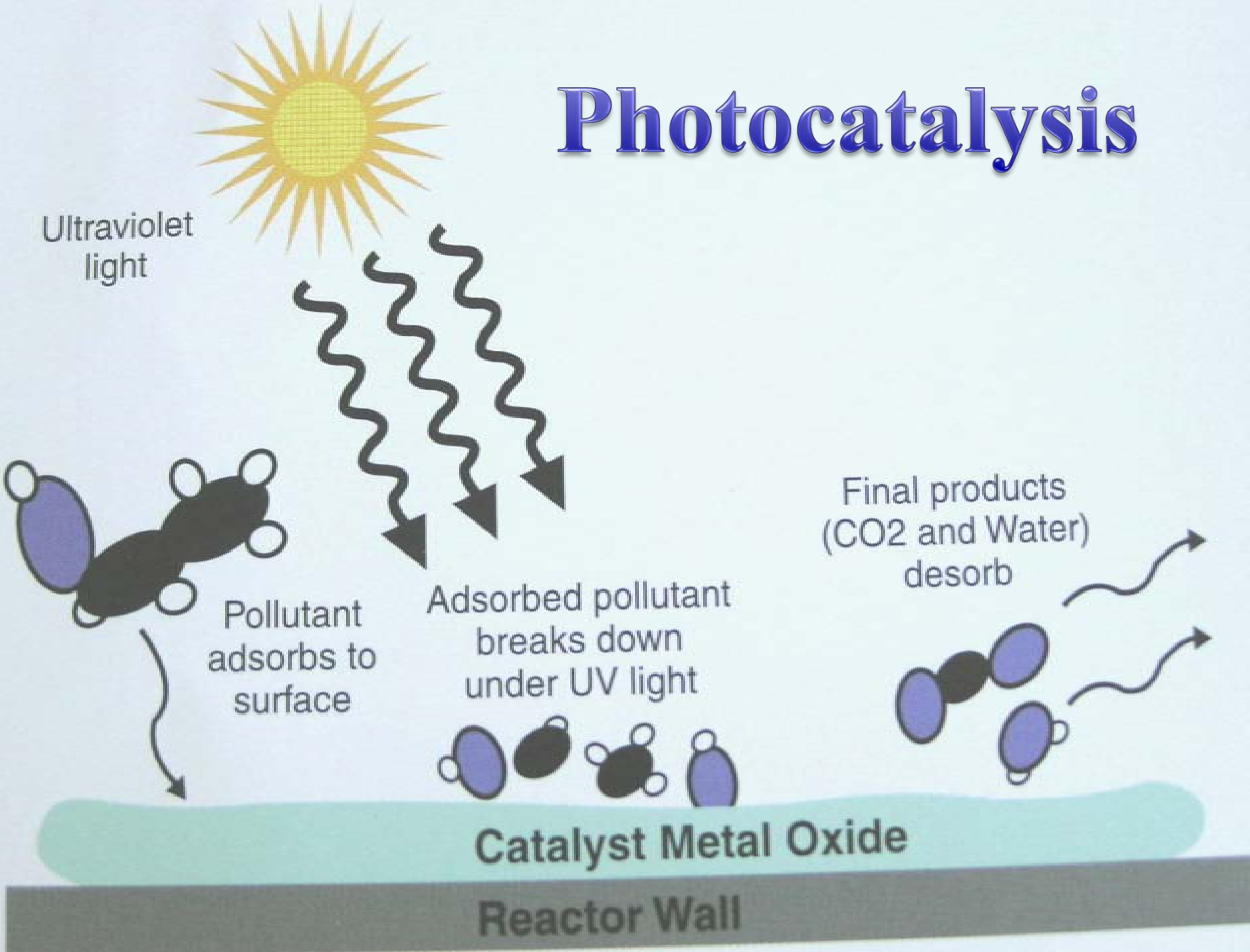
- **Drinking water production**: Disinfection: extensive chemicals treatments, e.g., chlorine, and high power UV expose.
- **Waste water treatment** (industrial and municipal): Decontamination (metal ions): extensive chemicals treatments , e.g., chelating chemicals, and absorbents, or membrane technology
- **Seawater desalination:** reverse osmosis membrane

Engineering "natural" systems for water purification

- Next-generation systems: **low-environmental-impact, low-energy-intensive, and high efficiency**
  - **Solar photocatalytic detoxification and disinfection**: solar reactors, photocatalyts, hybrid photocatalytic-biological process, and photocatalytic membrane process.
  - **Micro/nanotechnology in water purification**: carbon nanotubes membranes, nanofiber membranes, nanoporous ceramics, clays, and micro/nanofluidics.

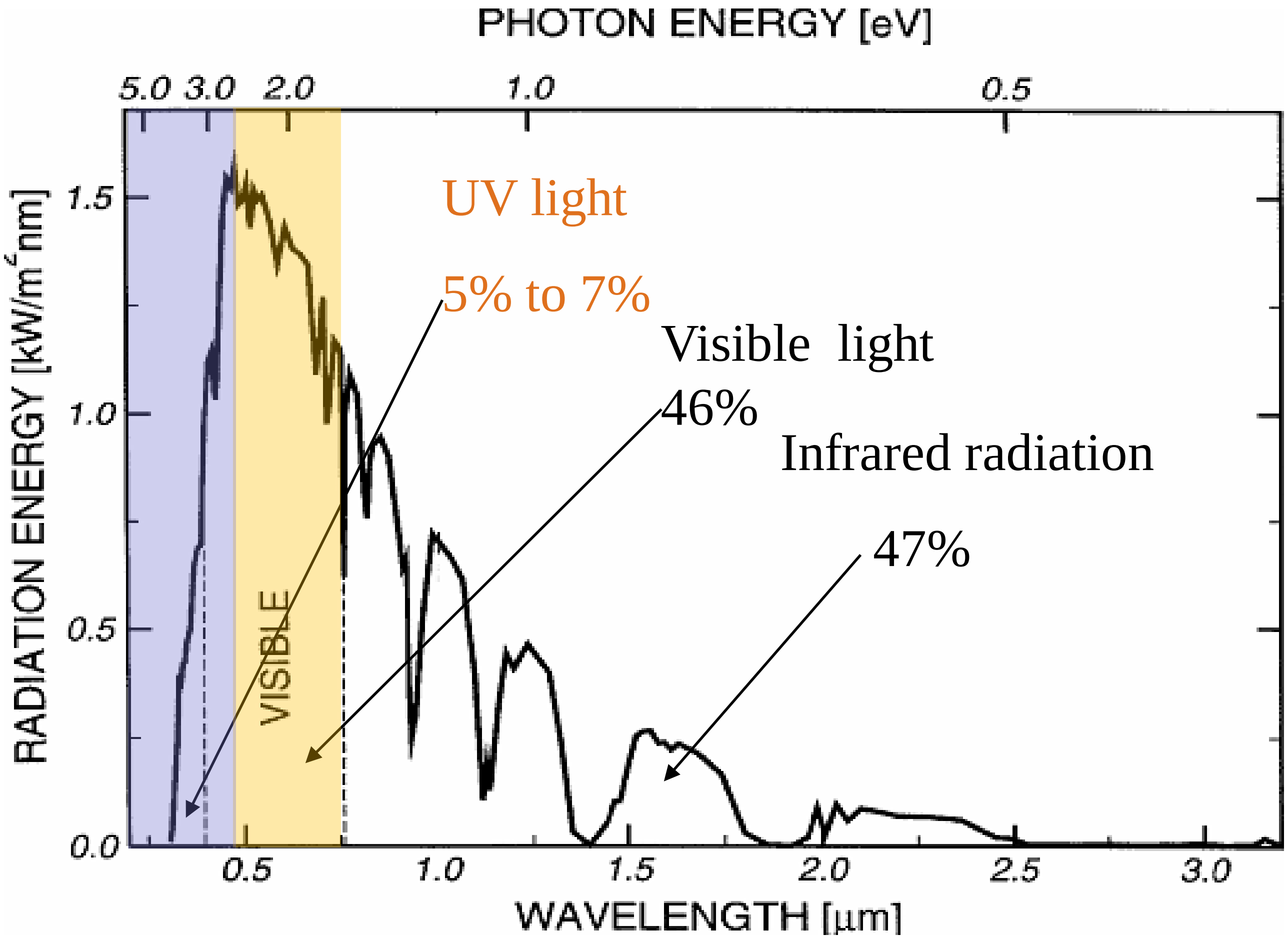
Peters, et al. *Chem. Eng. Technol. 2010,* ***33****, 1233–1240*. Shannon, et al. *Nature*, 2008, **452**, 301-310. Hochstrat, et. al. *Desalination and water treatment*, 2010, **18**, 96-102. Valli, et al. *Int. J. Nuclear Desalination,* 2010 , **4,** 49-57. Blanco-Galvez, et al. *J Solar Energy Engineering.* 2007, **129,** 4-15.

Photocatalysis

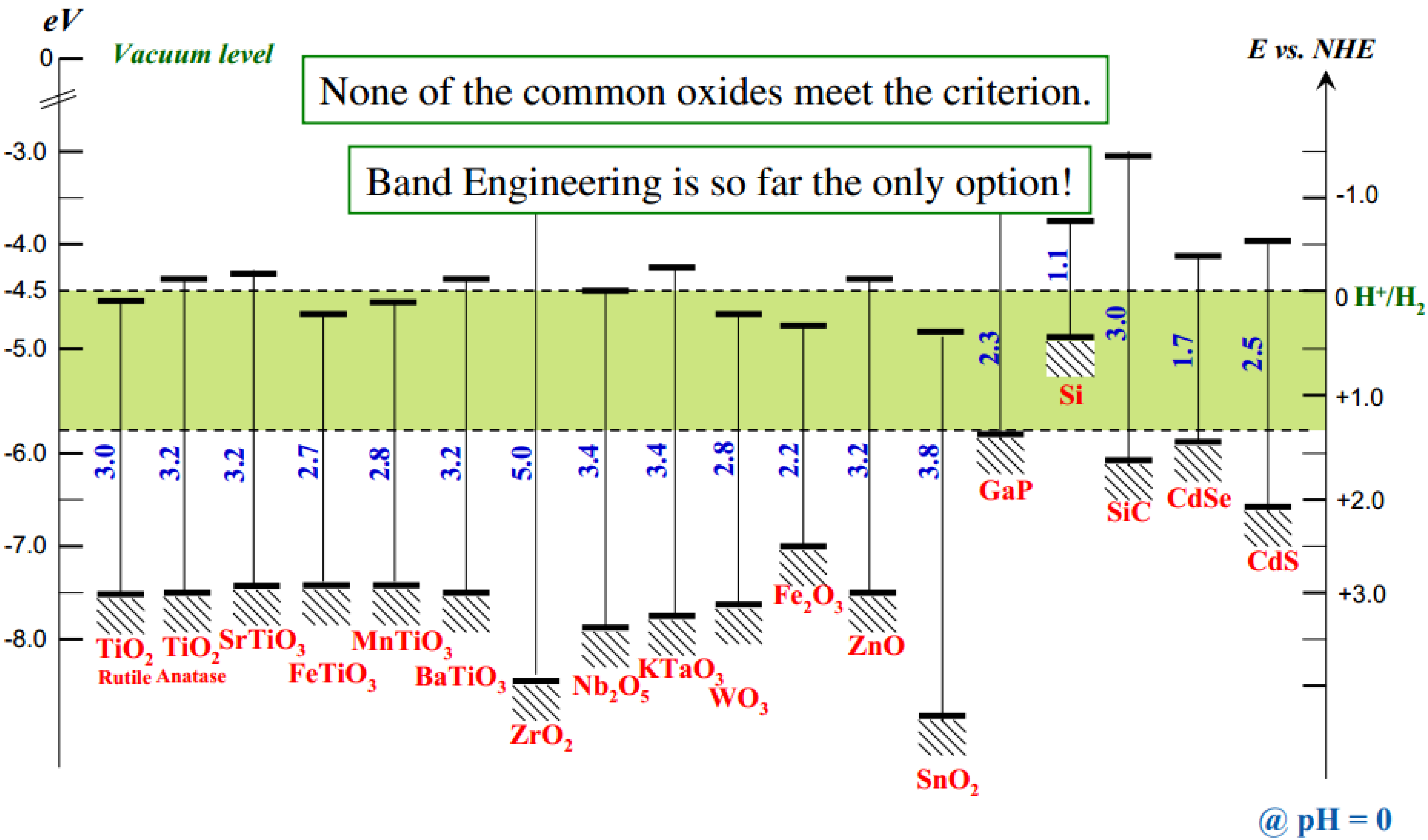


Solar spectra

86,000 TW/year energy on earth
(World consumption 15 TW/year)



Band Gap Positions in Various Semiconductors

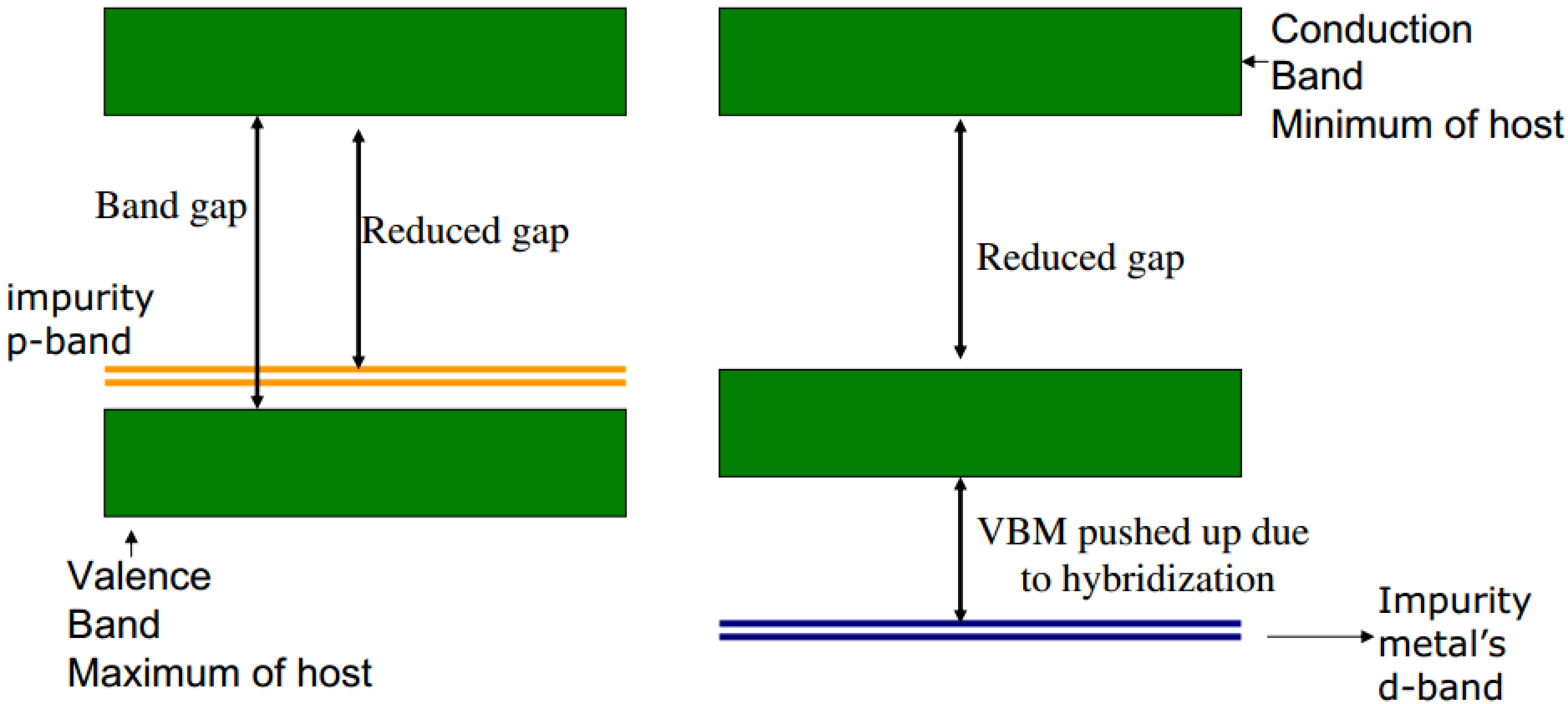


TiO_2, ZnO, Cu_2O, CuO, Fe_2O_3, CaO, MgO, BaO, La_2O_3, Ta_2O_5, PbO, SnO_2, Bi_2O_3, WO_3, CeO_2, In_2O_3,
Nb_2O_5, SiO_2, Al_2O_3, ZrO_2, Cr_2O_3, Ga_2O_3

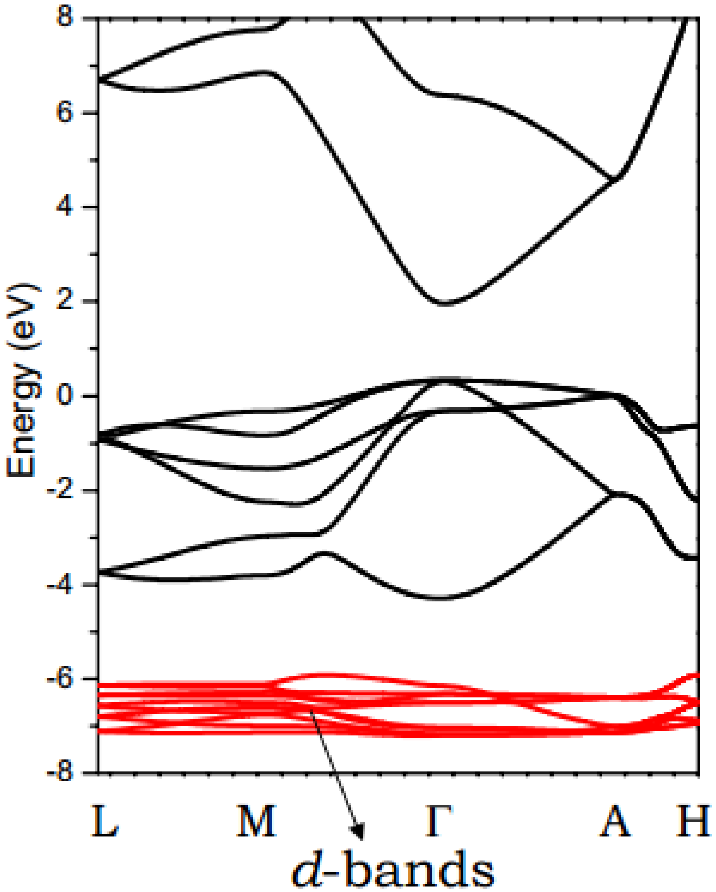
"There are easily 50,000 combinations of ternary oxides and almost 2 million quaternary oxides."

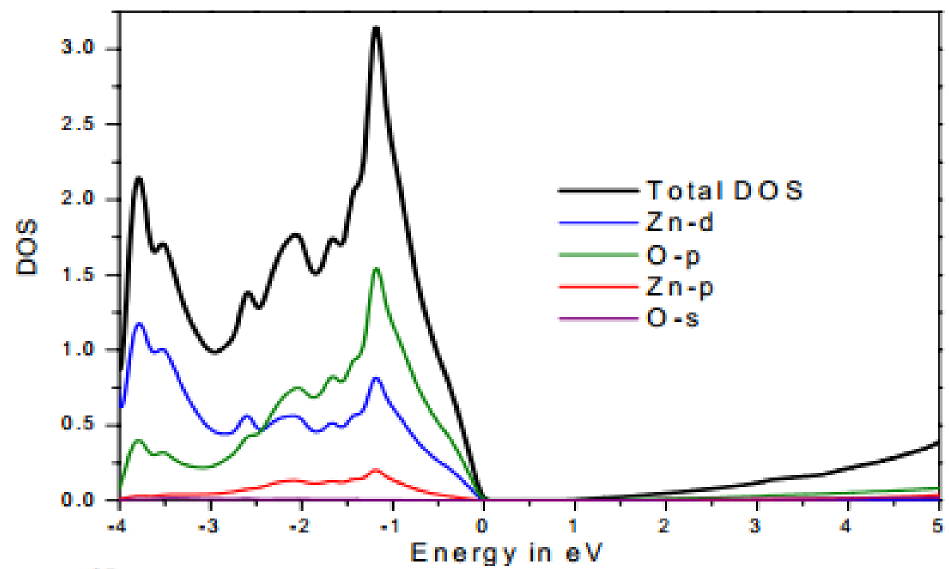
What do we mean by “band engineering”?

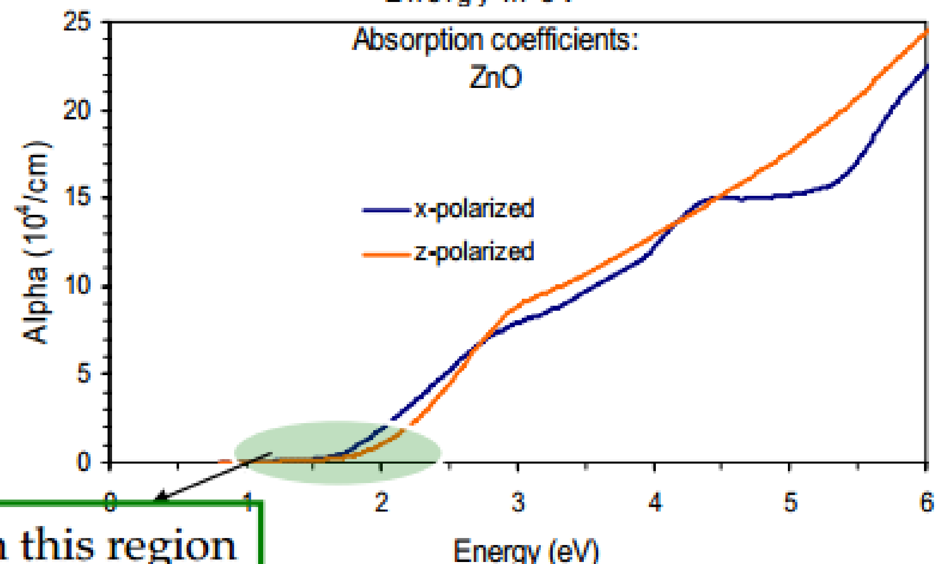
- Reduce the band gap.
- Have the right position of the band-edges.



Band engineering of ZnO







Goal is to improve absorption in this region

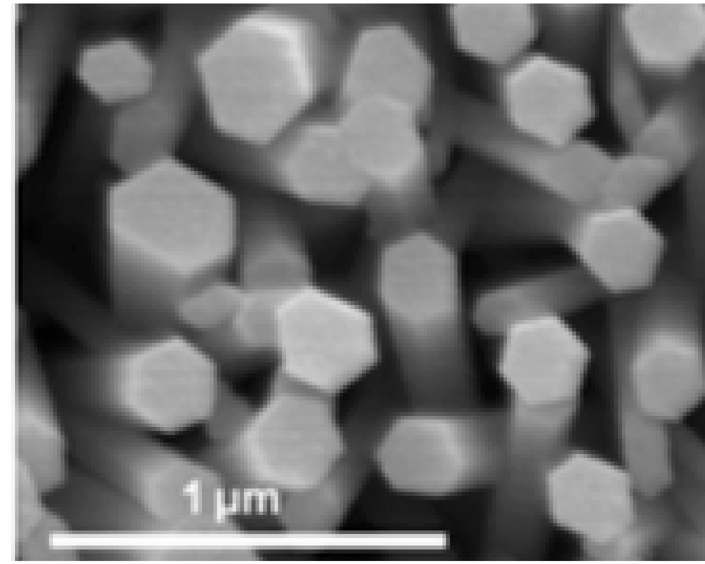
Defects…not always bad!

Corundum

Ruby

Beryl

Emerald



Defects in the crystal can make it absorb visible light

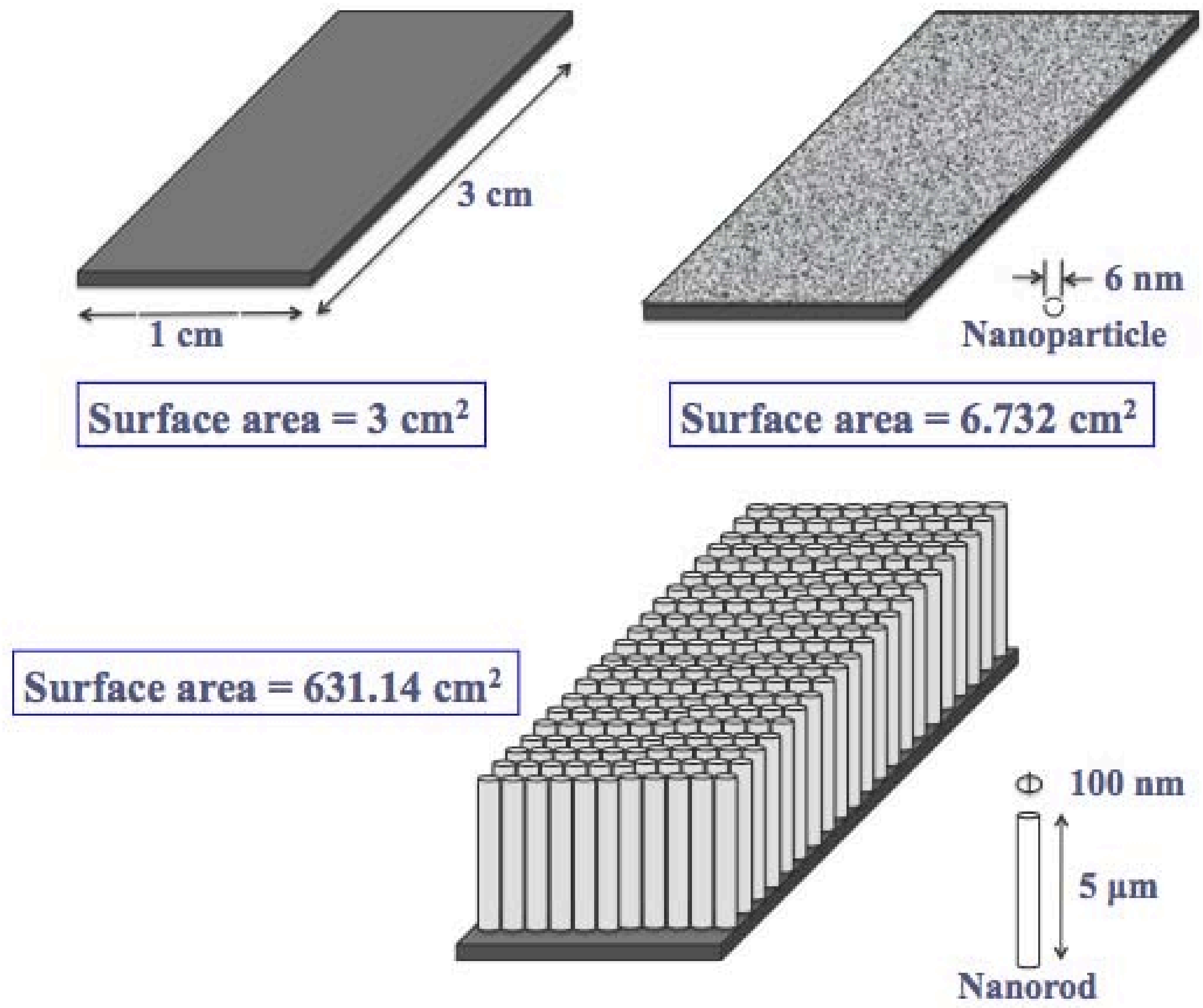
ZnO absorbs ultraviolet light

Baruah, S, Rafique R F and Dutta,J (2008) *Nano* **3** 399–407, IF 1.1

http://www.sciencesway.com/vb/t17685.html

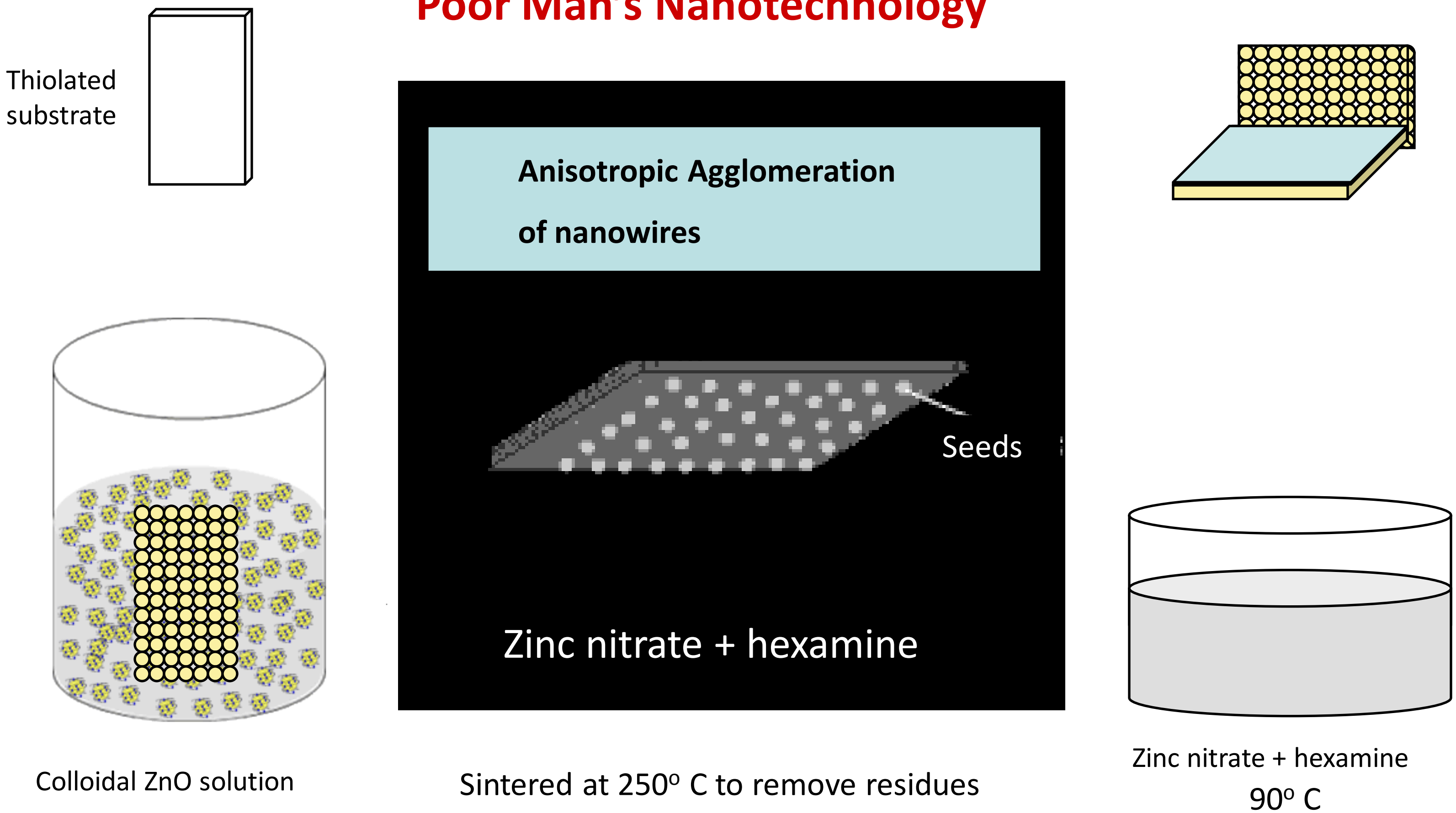
Catalyst on support

Surface area: crucial for photocatalysis !



Growth of ZnO nanowires

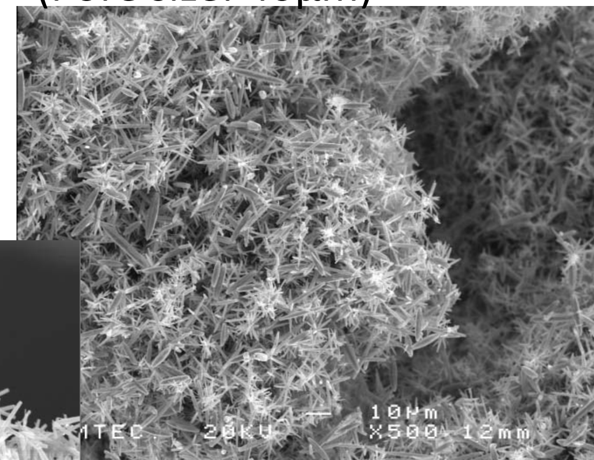
Poor Man's Nanotechnology



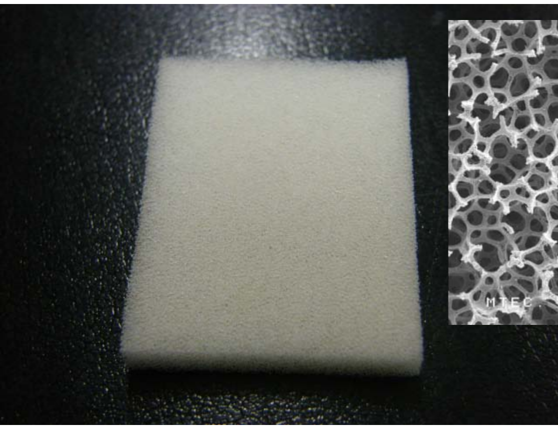
S. Baruah and J. Dutta, Science & Technology of Advanced Materials 10 (2009) 013001

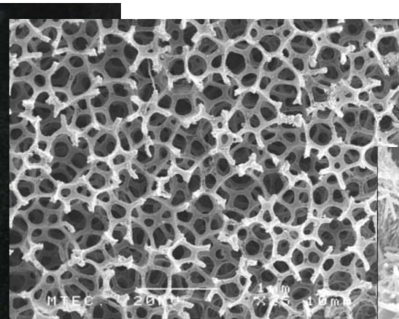
ZnO nanowires on CATALYST SUPPORTS

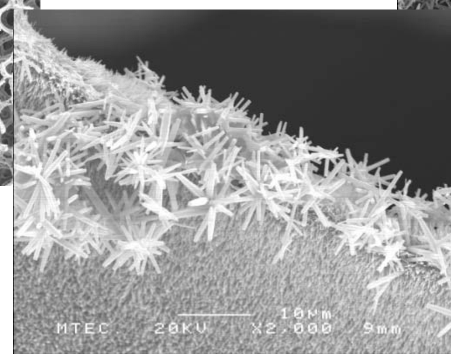
Stainless Steel Porous Metal
(Pore size: 40μm)



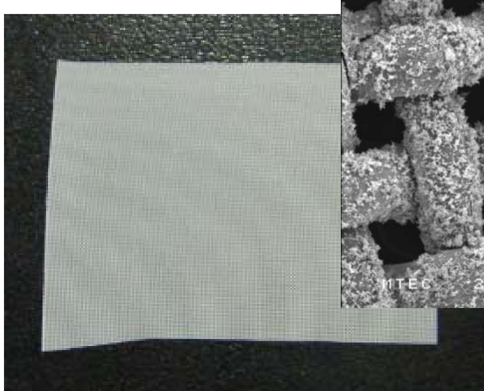
Polyurethane Foam (Pore size: 55-65 micron)

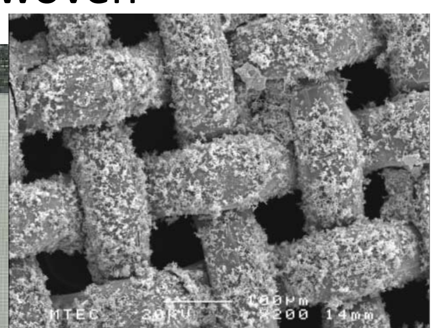




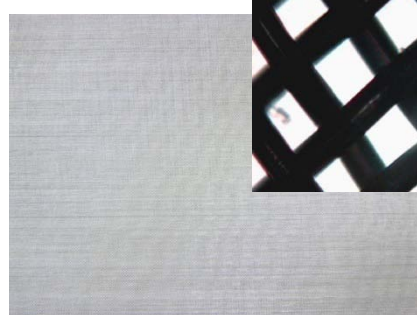


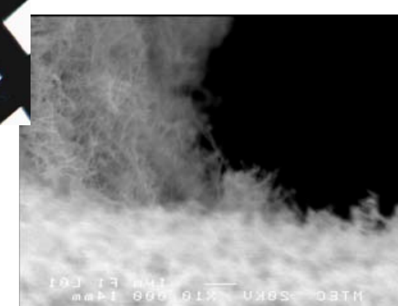
Polyester Scrim-woven





Stainless Steel Screen (Mesh size: 150 x 150 μm)





Photocatalysis

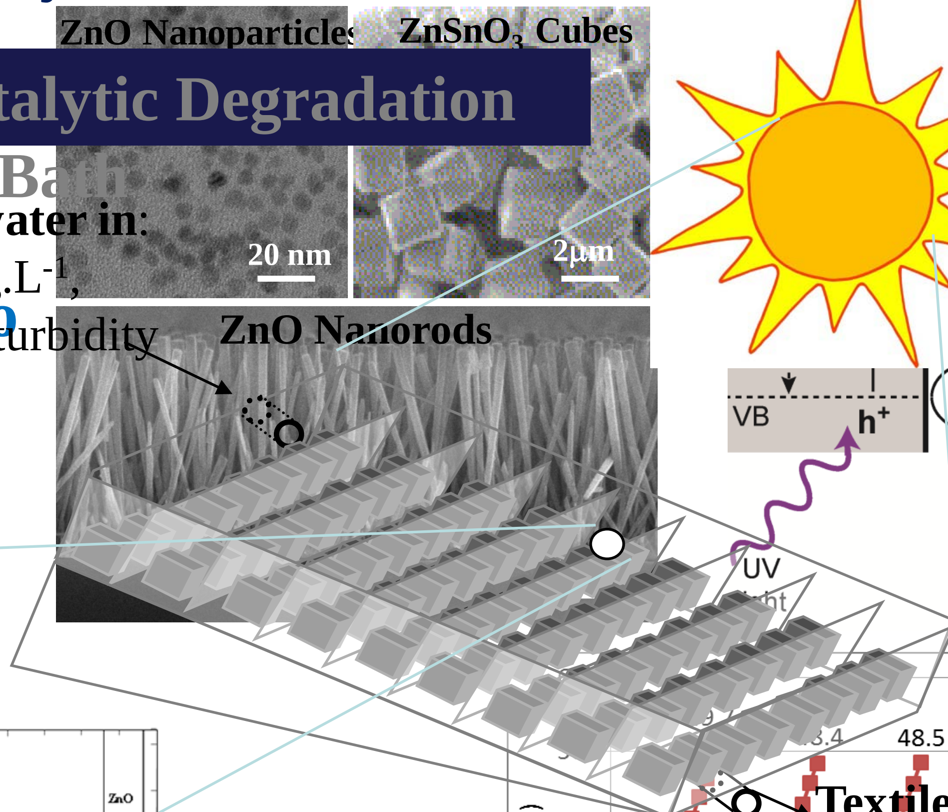
Designer Photocatalyst

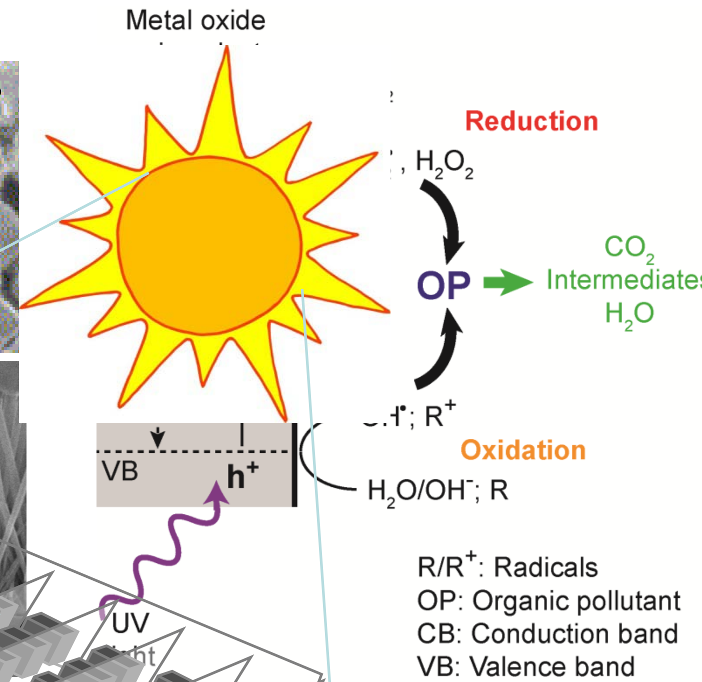
Solar Photocatalytic Degradation

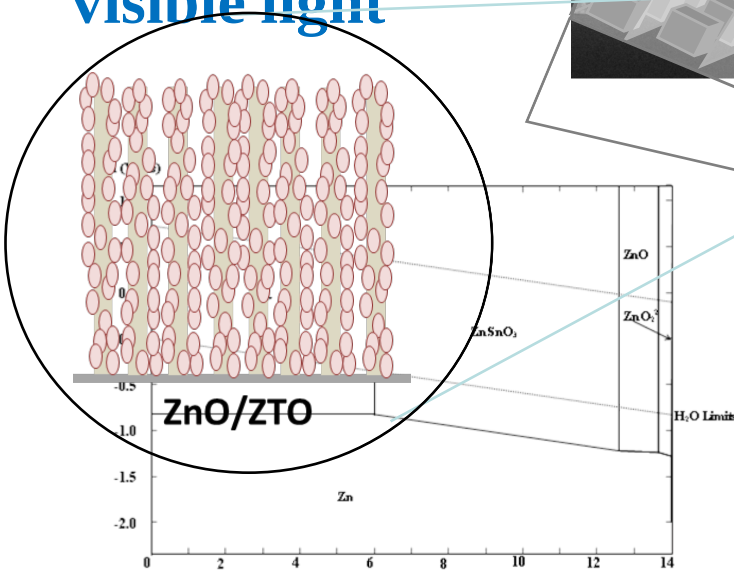
- ✓ Active against organic pollutants, microbes
- ✓ Active under visible light

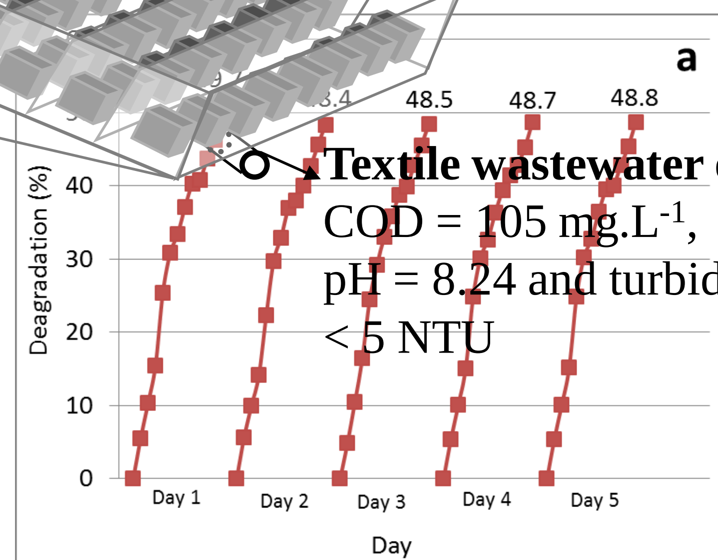
Bath

Textile wastewater in:
COD = 465 mg.L^{-1},
pH = 8.37 and turbidity = 60 NTU





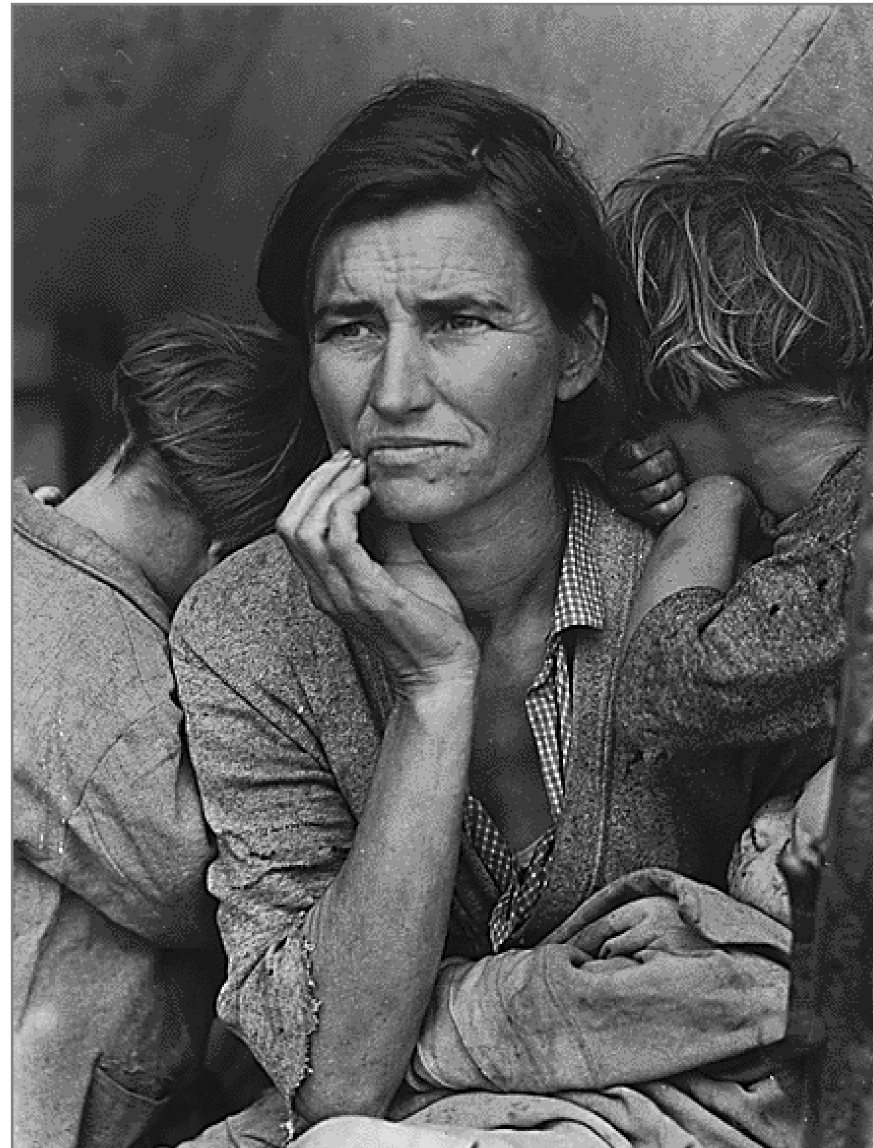




Textile wastewater out:
COD = 105 mg.L^{-1},
pH = 8.24 and turbidity < 5 NTU

S Danwittayakul, M Jaisai, J Dutta
Applied Catalysis B: Environmental 163 (2015) 1-8

Microbes in water?



49

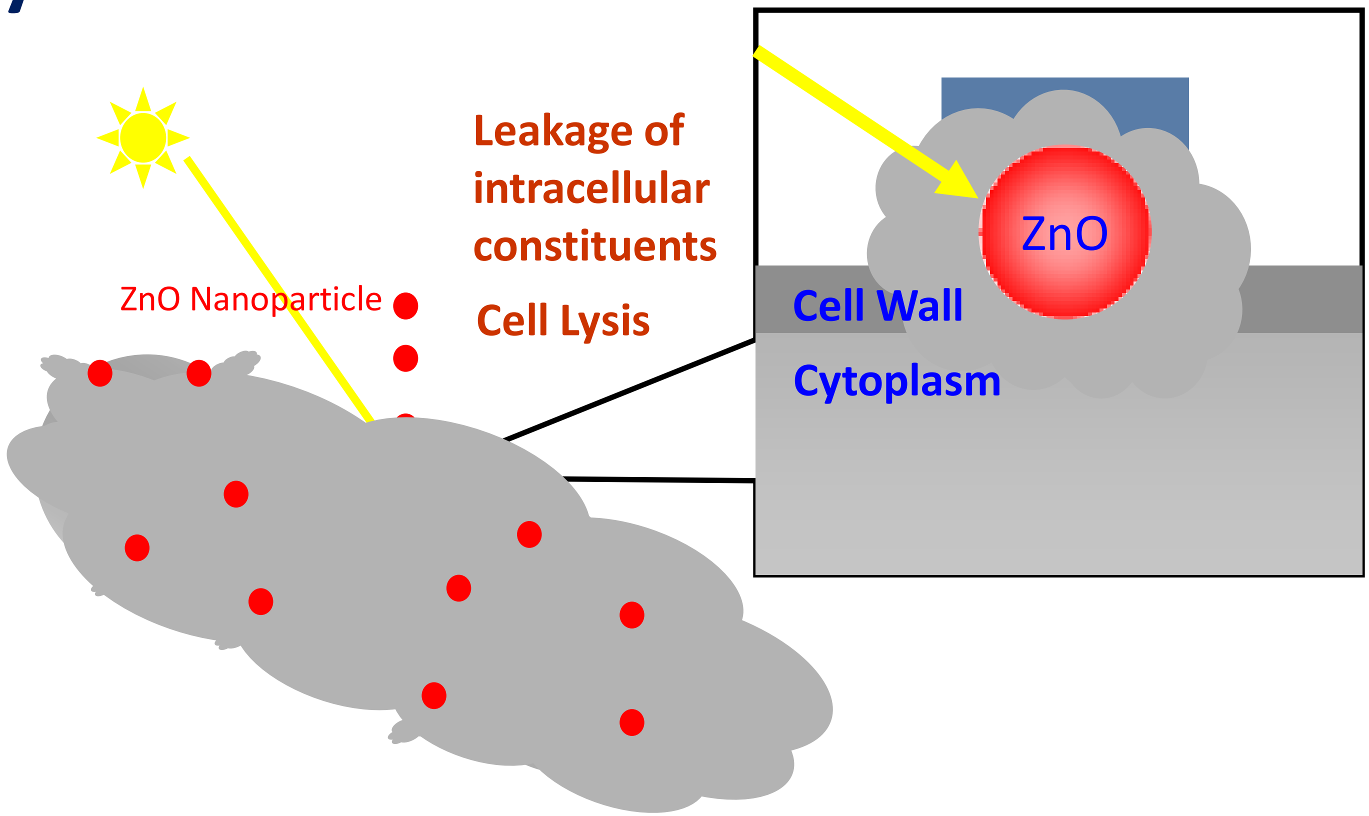
people

DIE

over **15 min** in the world

due to pathogen–contaminated water

Mechanism of Microbial Inactivation by Photocatalysis

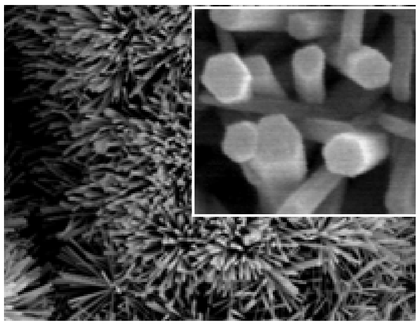


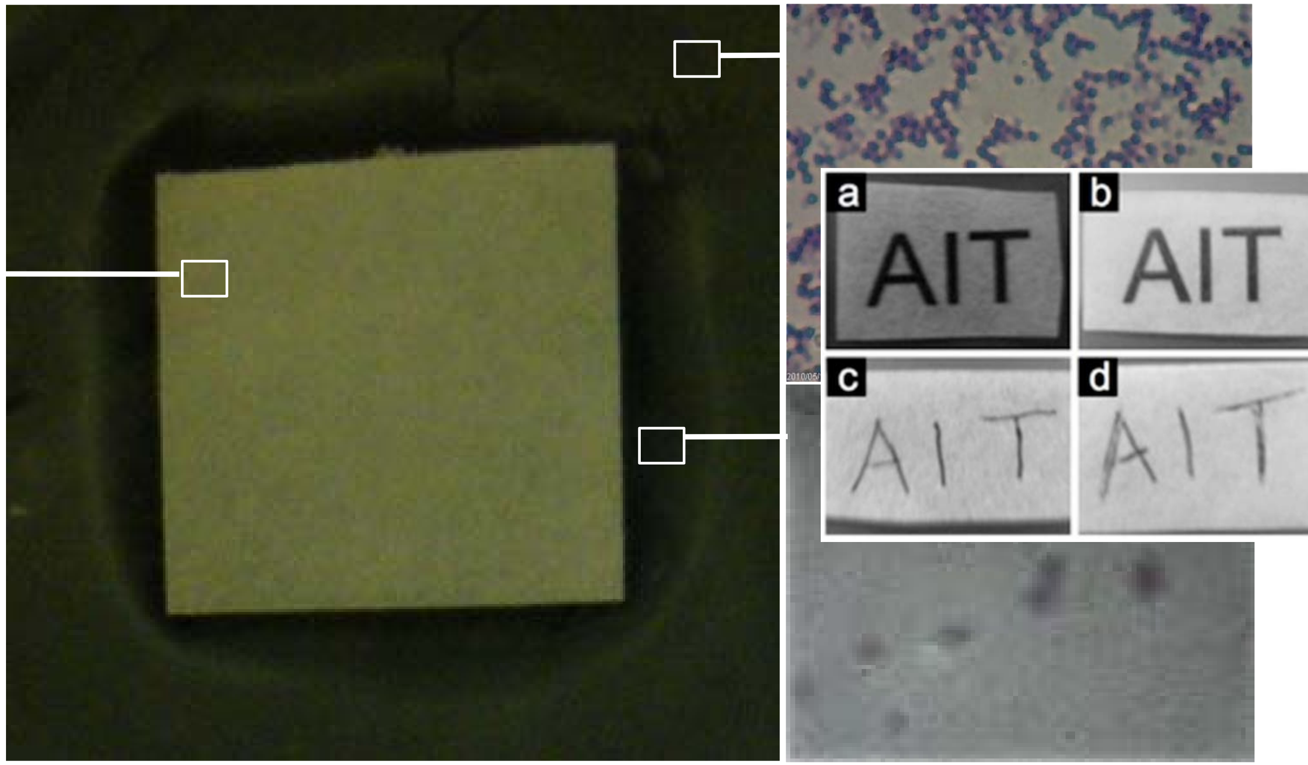
- Photocatalyst should be in contact with the cell surface for membrane damage to occur

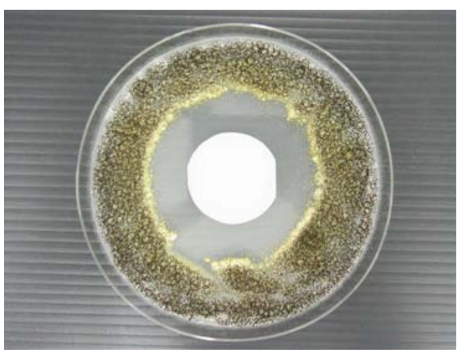
Ajaya Sapkota, Alfredo J Anceno, Sunandan Baruah, Oleg V Shipin and Joydeep Dutta, Nanotechnology 22 (2011) 215703 (7pp)

S Baruah, M Jaisai, J Dutta, Catal. Sci. Technol. 2 (2012), 918-921

Photocatalytic paper: ZnO nanorods on cellulose supports







Baruah, S, Jaisai, M, Imani, R, Nazhad, M M and Dutta, J (2010) *Science and Technology of Advanced Materials* **11** 055002

R. Imani, M. Talaiepour, J. Dutta, M. R. Ghobadinezhad, A. H. Hemmasi and M. M. Nazhad, *BioResources* 6 (2011) 891-900

M Jaisai, S Baruah, J Dutta, Beilstein Journal of Nanotechnology 3 (2012), 684-691

ZnO nanorods based water purifier

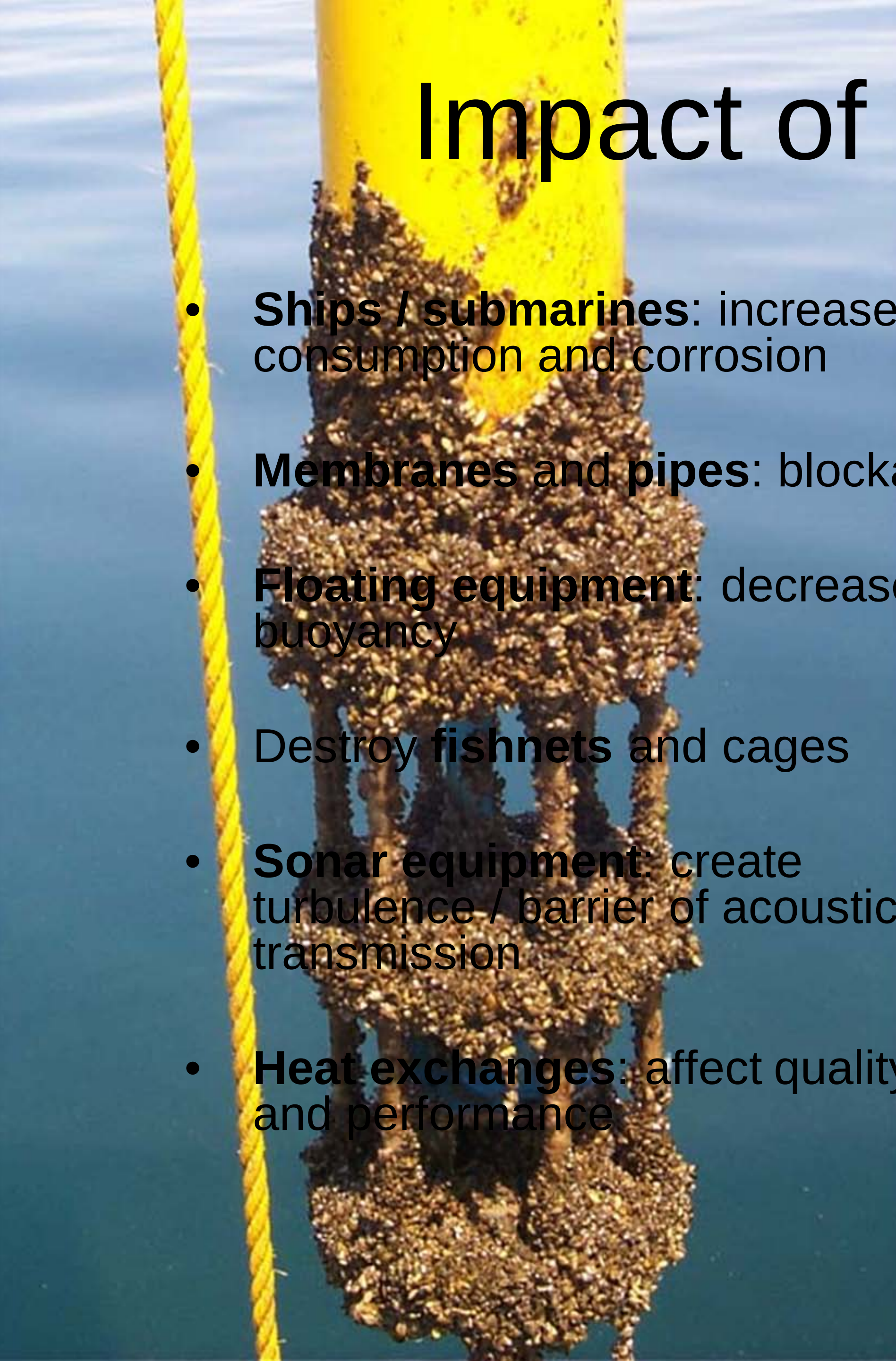
The vision:

Mohammed Abbas Mahmood, Sunandan Baruah, Anil Kumar Anal and Joydeep Dutta
Environmental Chemistry for a Sustainable World Vol. 2: Remediation of Air and Water Pollution,
Eds. Eric Lichtfouse, Jan Schwarzbauer and Didier Robert (2012), Springer, ISBN 978-94-007-2438-9

MA Mahmood, S Baruah, AK Anal, J Dutta, Environmental Chemistry Letters 10 (2012), 145-151
S Baruah, M Jaisai, J Dutta, Catal. Sci. Technol. 2 (2012), 918-921

Biofouling

Impact of biofouling

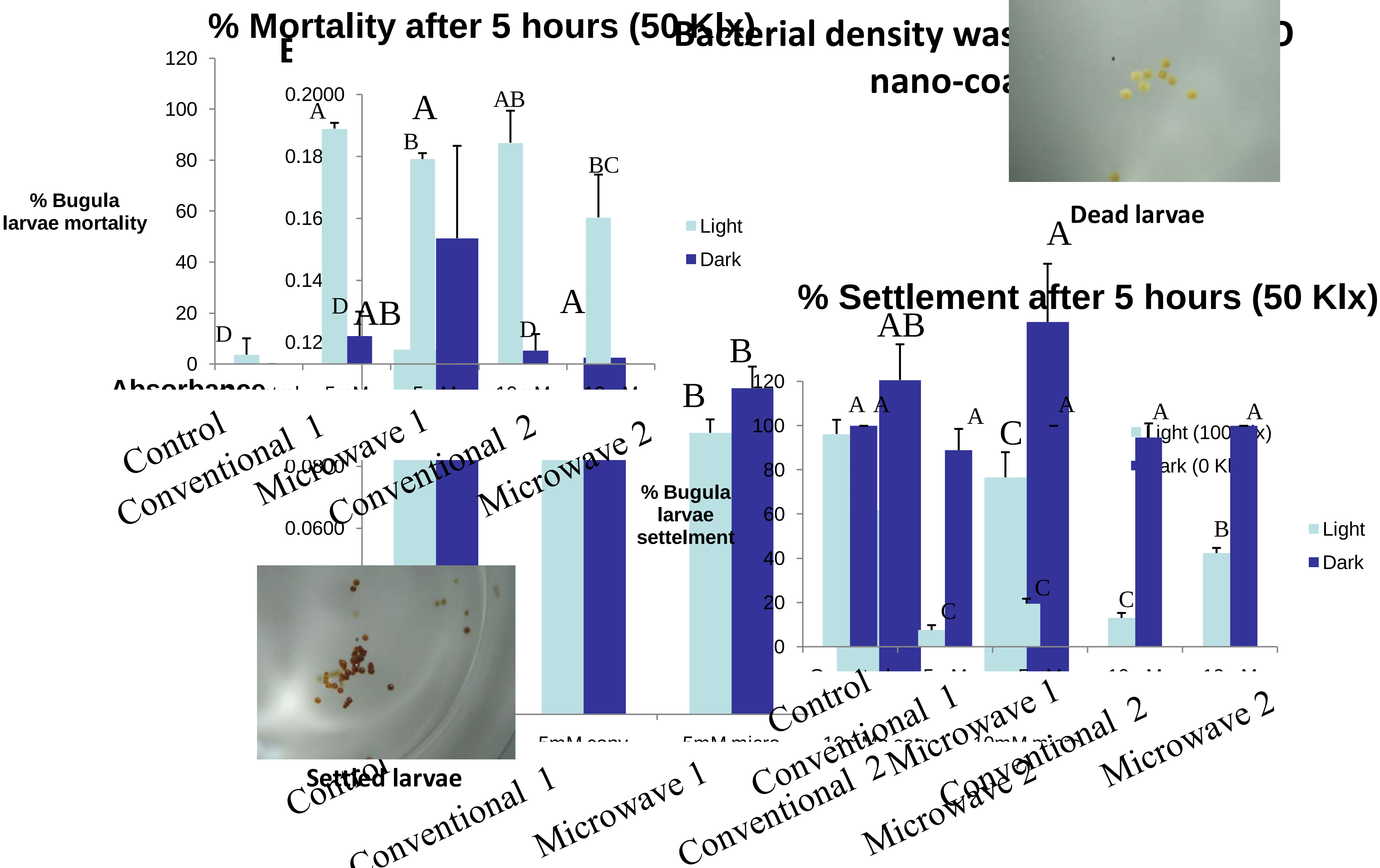


- **Ships / submarines**: increase fuel consumption and corrosion
- **Membranes** and **pipes**: blockage
- **Floating equipment**: decrease buoyancy
- Destroy **fishnets** and cages
- **Sonar equipment**: create turbulence / barrier of acoustic transmission
- **Heat exchanges**: affect quality and performance

Anti-larval assay

Bacterial density

Bacterial density was … D
nano-coa…



Dead larvae

Settled larvae

Harmful Algal Blooms (HABs)

Control

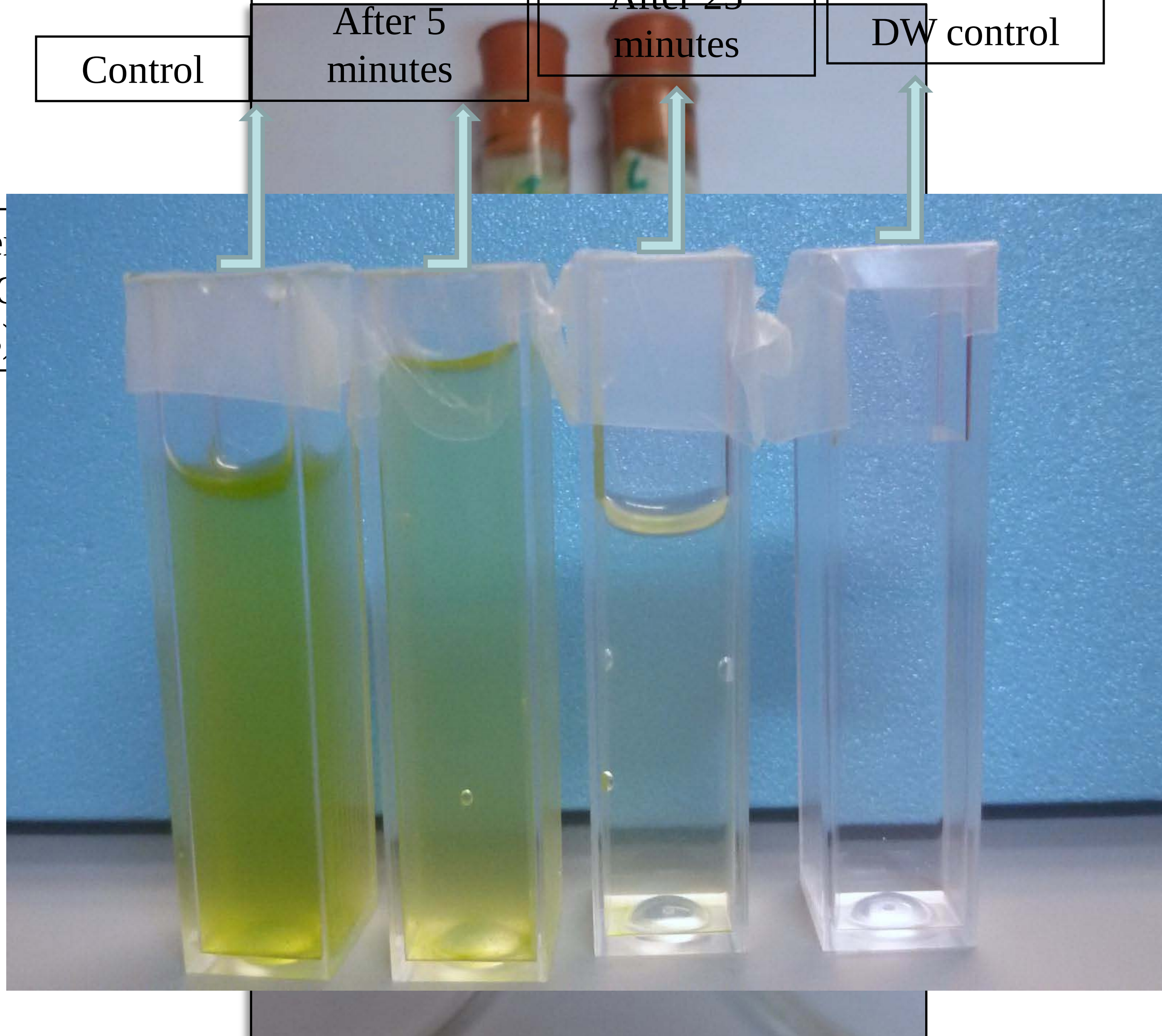
After 5 minutes

After 25 minutes

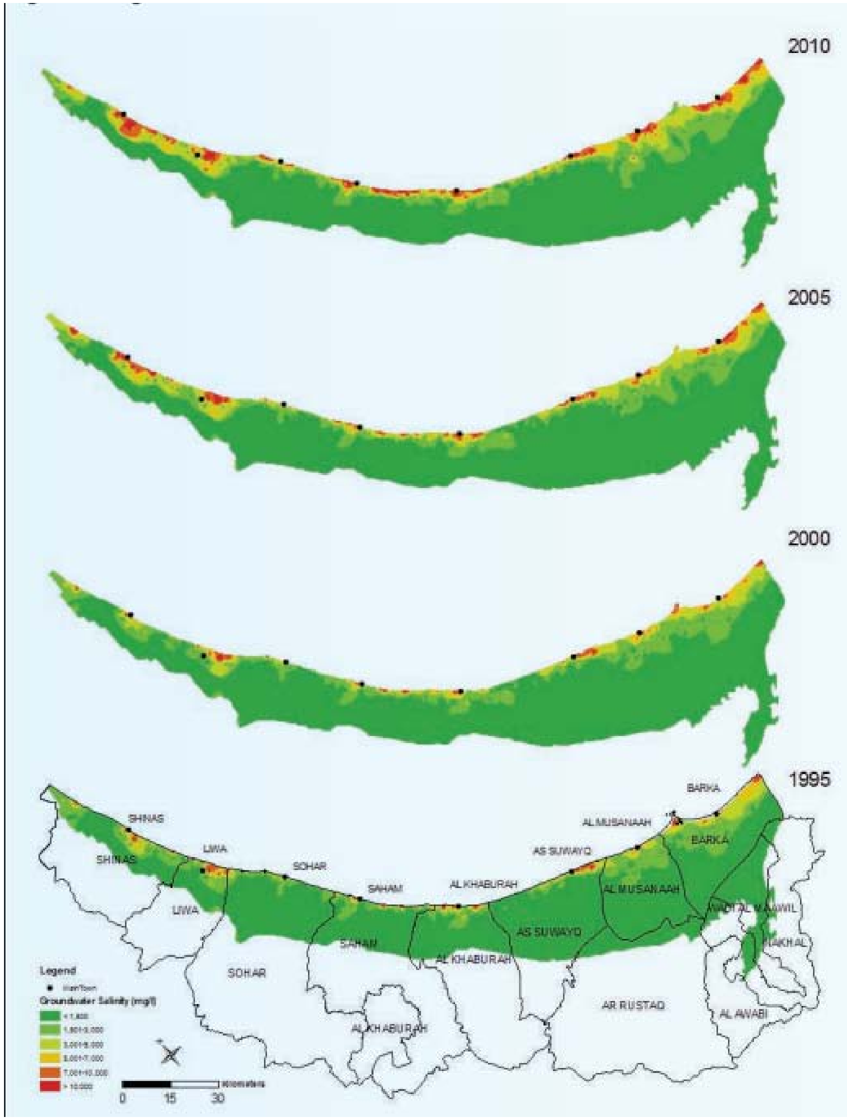
DW control

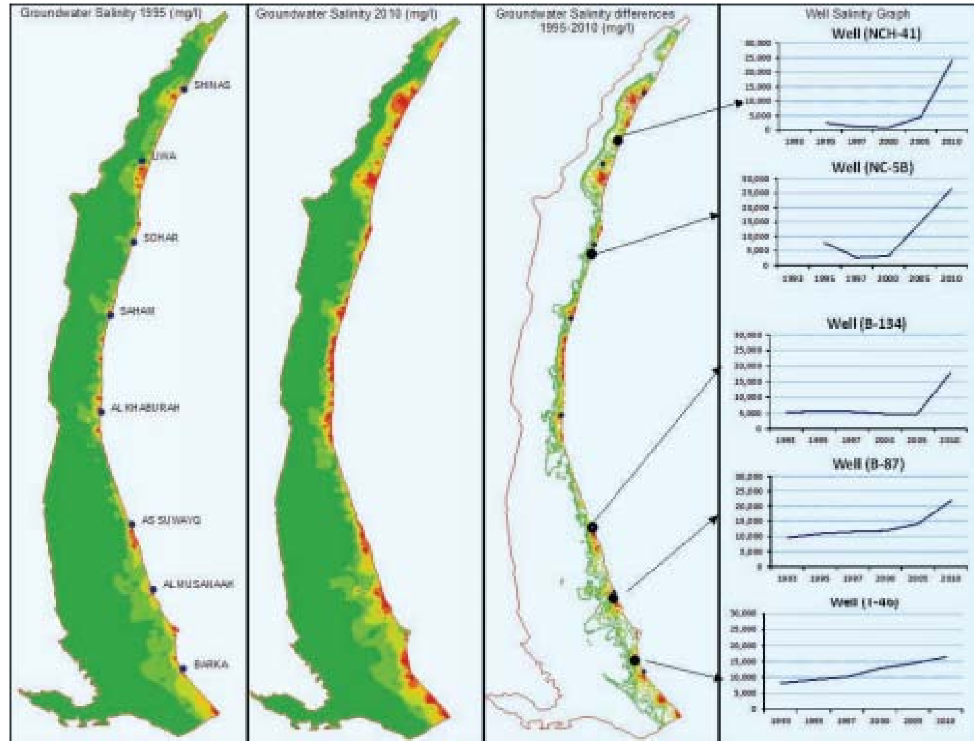
Test filte
(With ZnO
nanorods)

ntrol filter
thout ZnO
anorods)



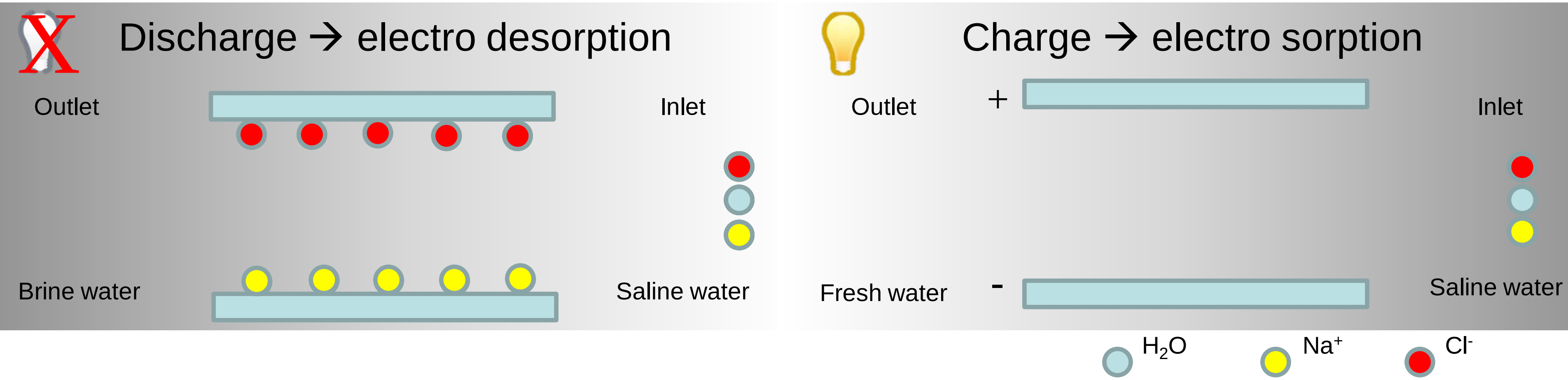
Saline water seepage



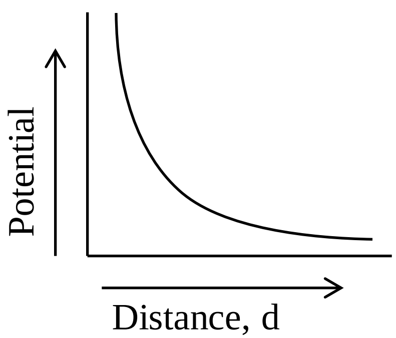


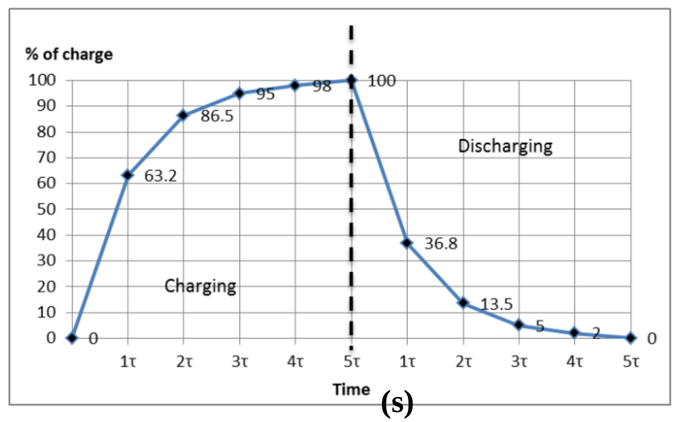
Source: GWI desaldata

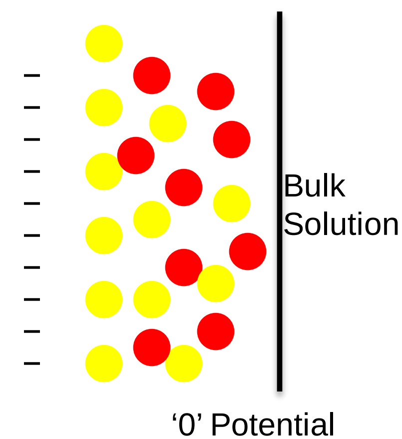
Capacitive De-ionization



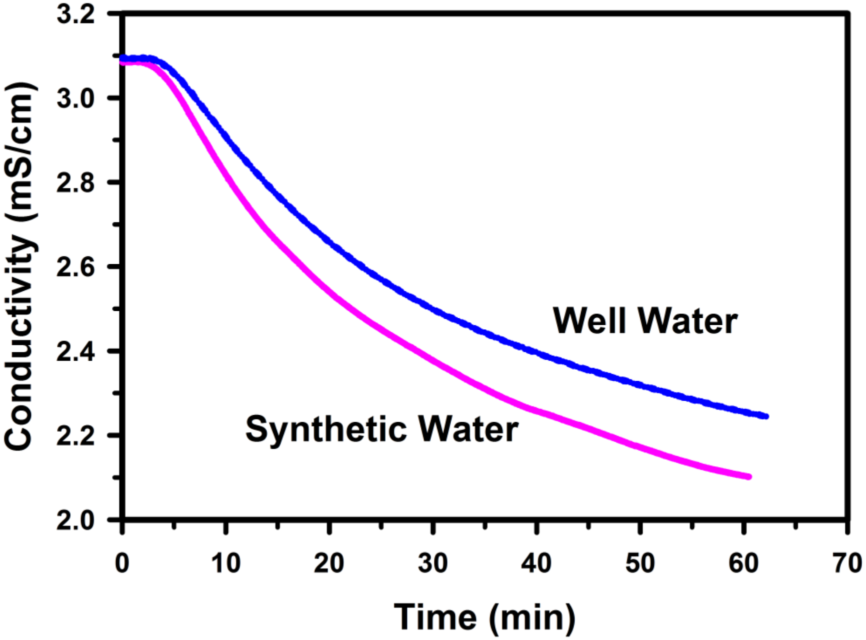
$$\text{Capacitance, } C = \frac{\varepsilon_r \, \varepsilon_0 \, A}{d}$$

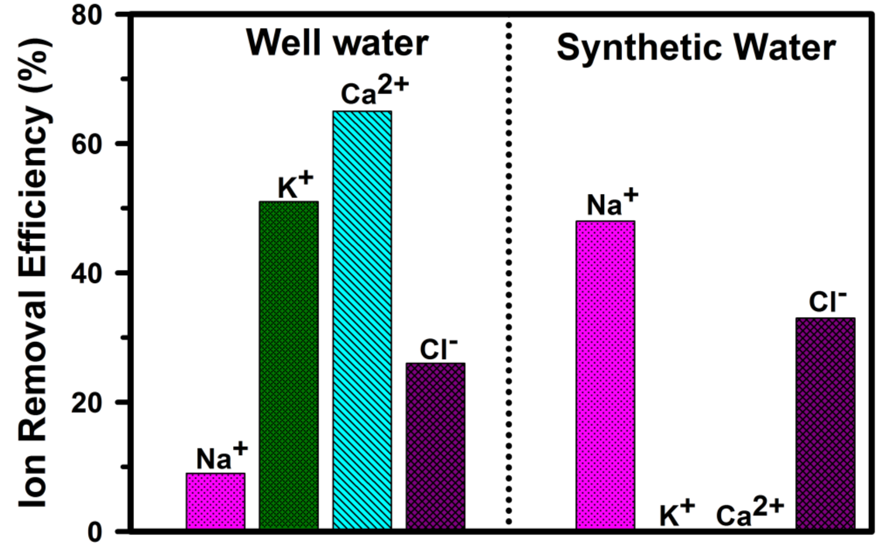




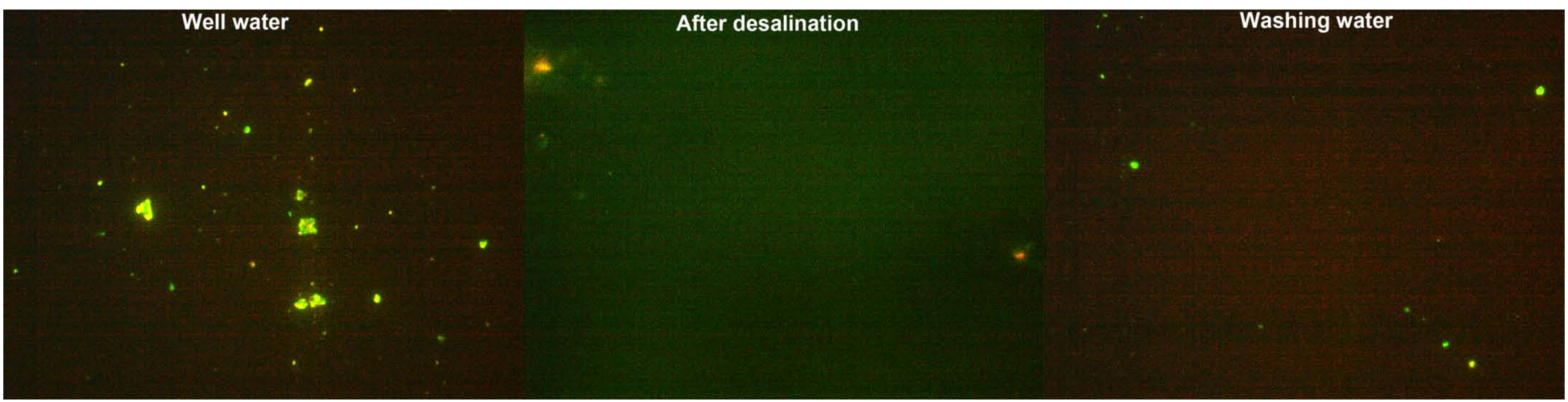


Al Musannah well water desalination

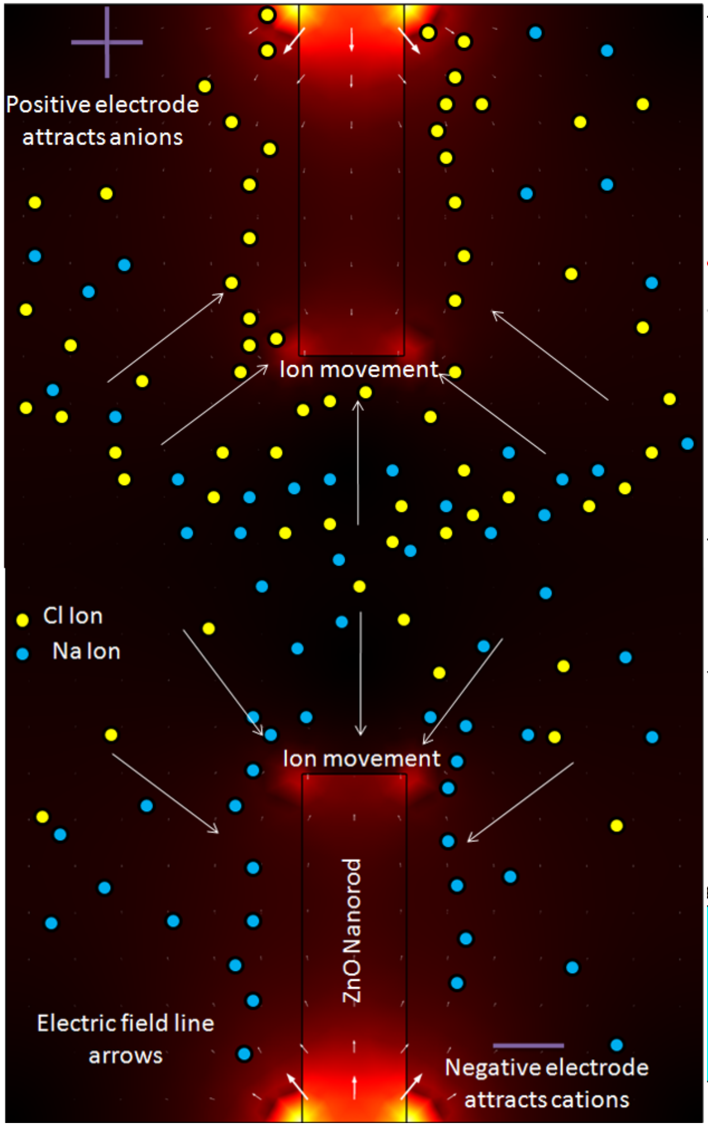


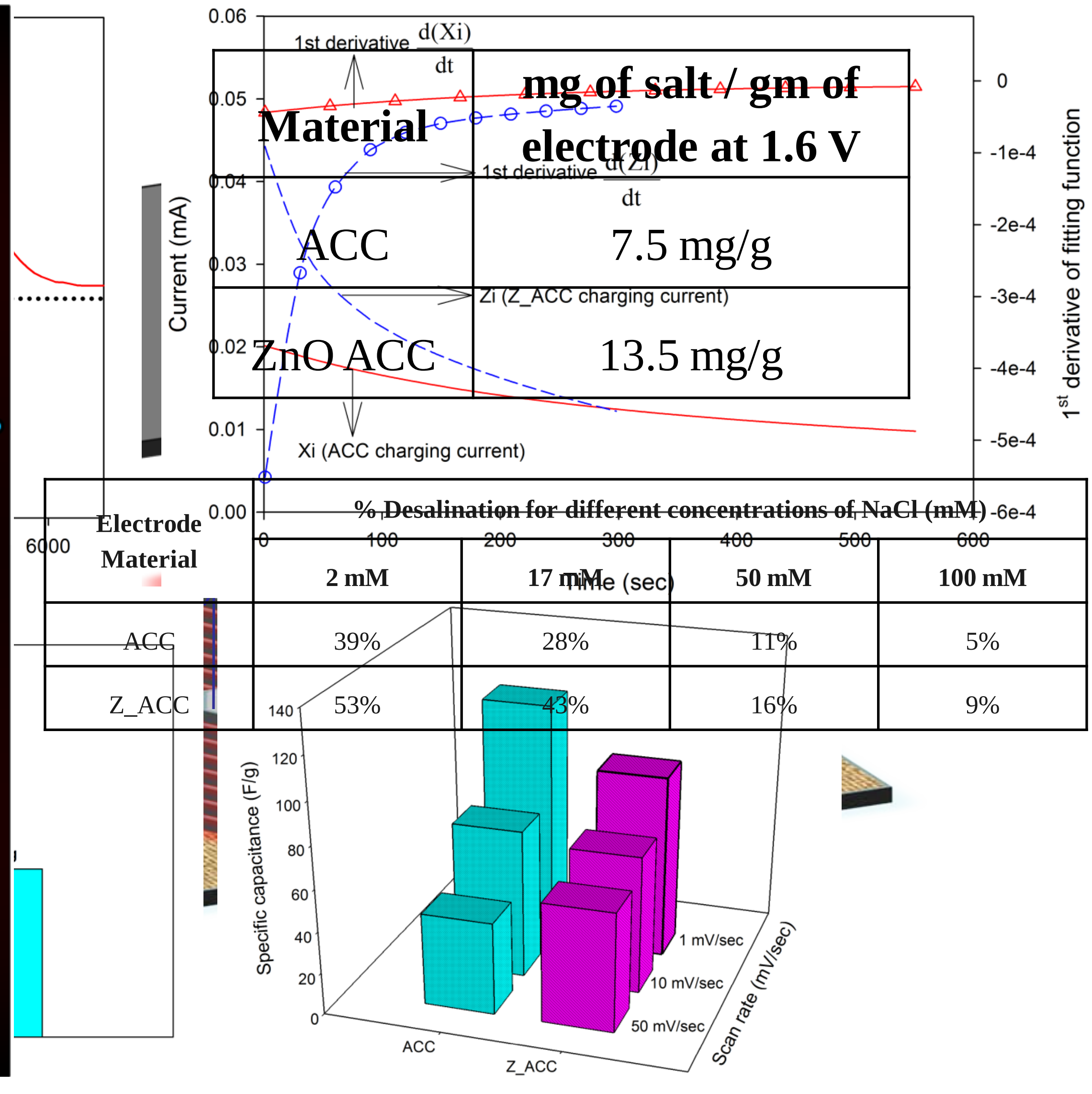


Disinfection Properties



Desalination Results

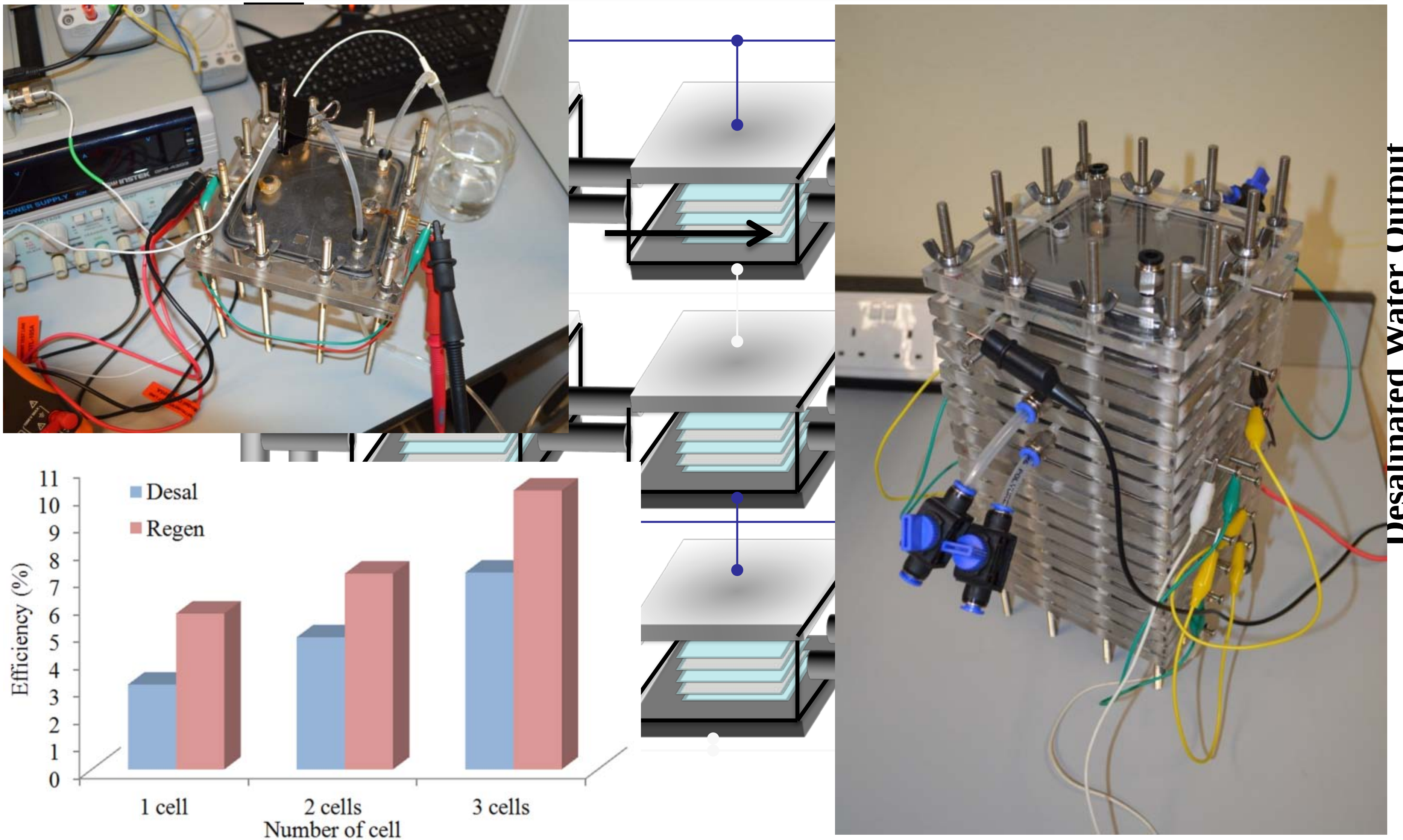




Material	mg of salt / gm of electrode at 1.6 V
ACC	7.5 mg/g
ZnO ACC	13.5 mg/g

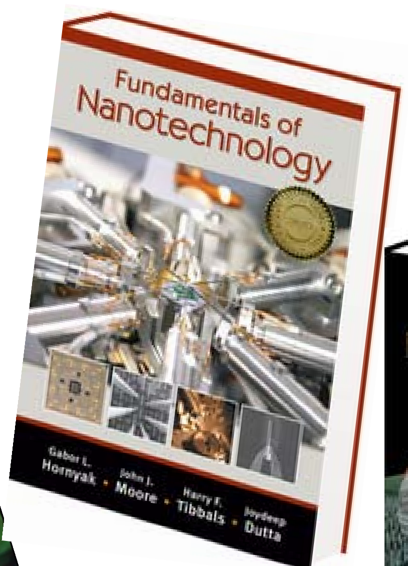
Electrode Material	% Desalination for different concentrations of NaCl (mM)			
	2 mM	17 mM	50 mM	100 mM
ACC	39%	28%	11%	5%
Z_ACC	53%	43%	16%	9%

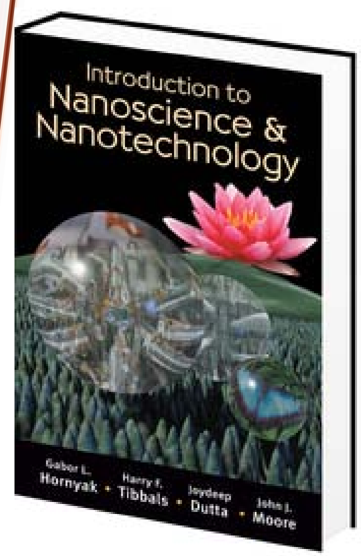
Desalination performance enhancement



Thank You

Nanotechnology
is the Future





- be a part of the revolution

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