Nanostructures for Water Purification

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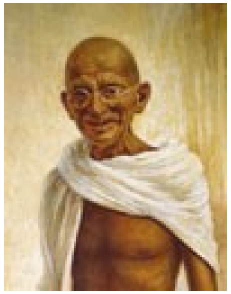
London’s Global University

- Over 4300 academic staff in 8 faculties
- Over 24,000 students (~1/3 overseas)
- Over 150 Fellows of the Royal Society, the British Academy, the Royal Academy of Engineering, and the Academy of Medical Sciences

- 21 Nobel Prize winners …

Charles Kuen Kao
(高锟)

Francis Crick

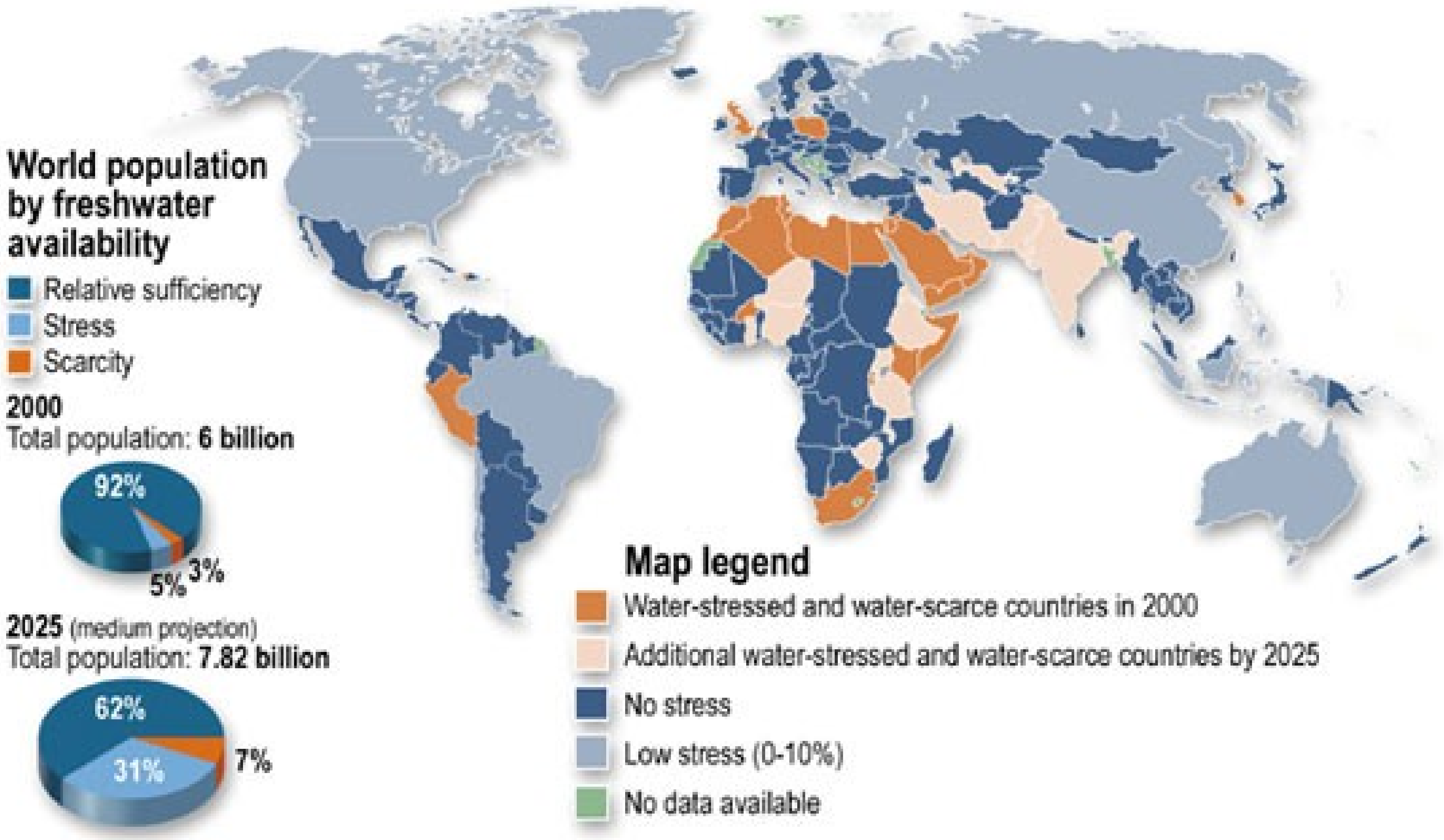


Mahatma Gandhi

UCL breakthroughs
- First transatlantic connection- the internet
- Identification of hormones and vitamins
- Discovery of inert gases, including neon (1st UK Nobel Prize in Chemistry)

…

“If all the earth's freshwater were stored in a 5-liter container, available fresh water would not quite fill a teaspoon…, ~ 0.08 – 1 % ”



(Source: World Water Council)

Water Resources Management - UCL

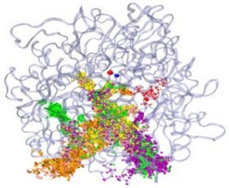
- rainfall simulation, recharge
- groundwater resources, aquifer characterisation
- threats to groundwater resources
- impacts of development
- water quality management
- optimization, and public perception

UCL Environment Institute

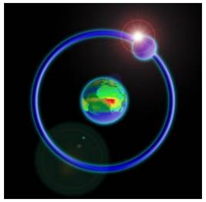
Nanostructures underpin technologies for clean - energy, environment & water

Carbon Capture: effective sorbants, membranes

PV / PEC: efficient photo-catalysts



Biofuels: sustainable processes; effective catalysts



H_2 Fuel:
- Generation: efficient membranes, catalysts
- Storage: high capacity, “hybrid” bonding

Batteries: electrode structures; fast kinetics

Key Research Facilities

Simulations:

- Computer cluster – 3000 CPUs; HPCx (national source);
- Software: WIEN2K, VASP, DL-POLY, QC.

Synthesis:

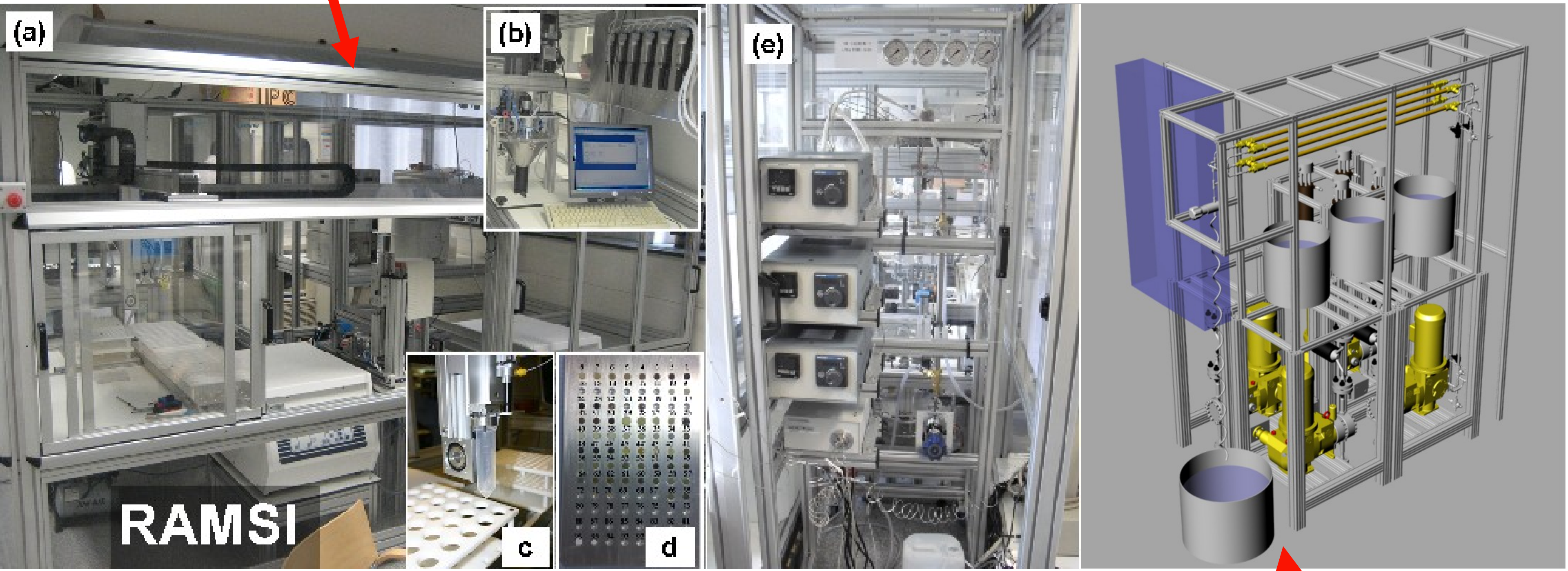
- Clean room; Clean powder synthesis: Planetary ball mills & Spex ball in a glove box; wet-chemistry (co-precipitation; sol-gel…)
- Novel multi-source PVD for nanostructures
- (in collaboration with Univ of East Anglia).

Characterisations:

- Simultaneous TG/DSC/MS/FT-IR/GC;
- Automated / Modified P-C-T;
- XRD,SEM,TEM,AFM.

UCL's Unique Solutions

RAMSI (Rapid Automated Materials Instrument)

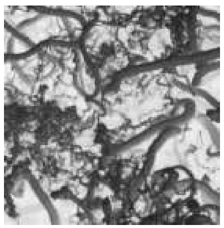


50 unique nanoceramics a day

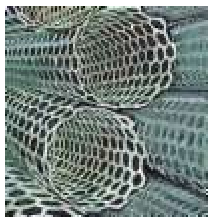
MINI-PLILOT PLANT
5 kg a day

(Dr. J. Darr, Prof. Z.X.Guo, Prof. J.R.E.G. Evans)

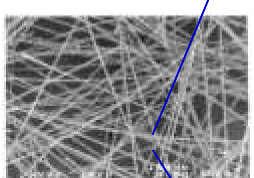
Carbon supported nanostructures offer high-density of hydrogen for PEM fuel cells…

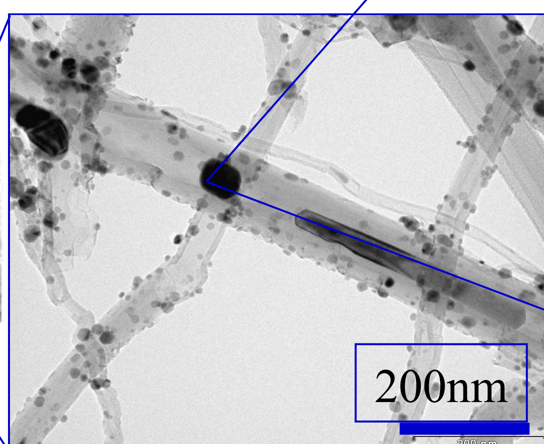


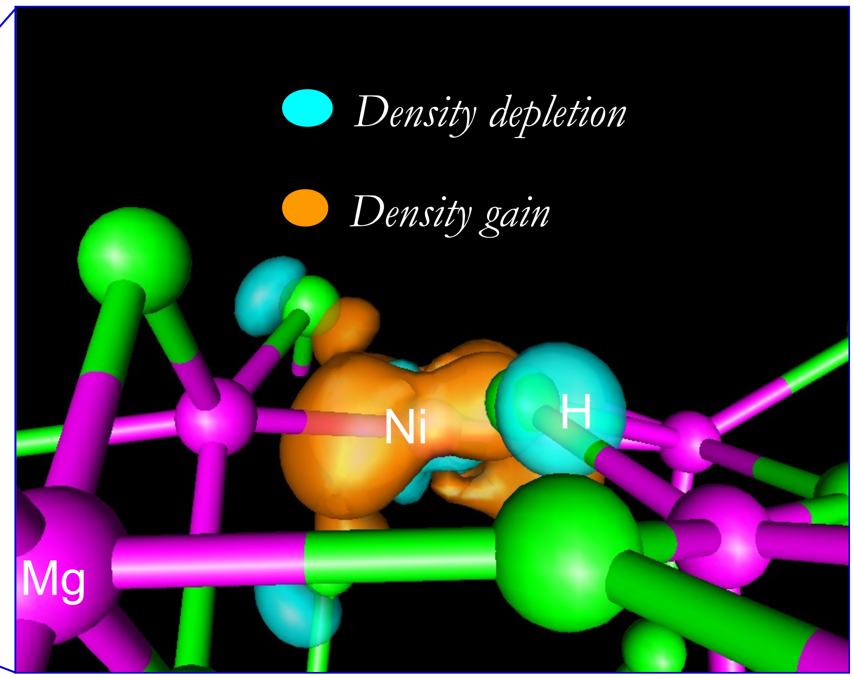
Carbon nanofibres



Carbon nanotubes



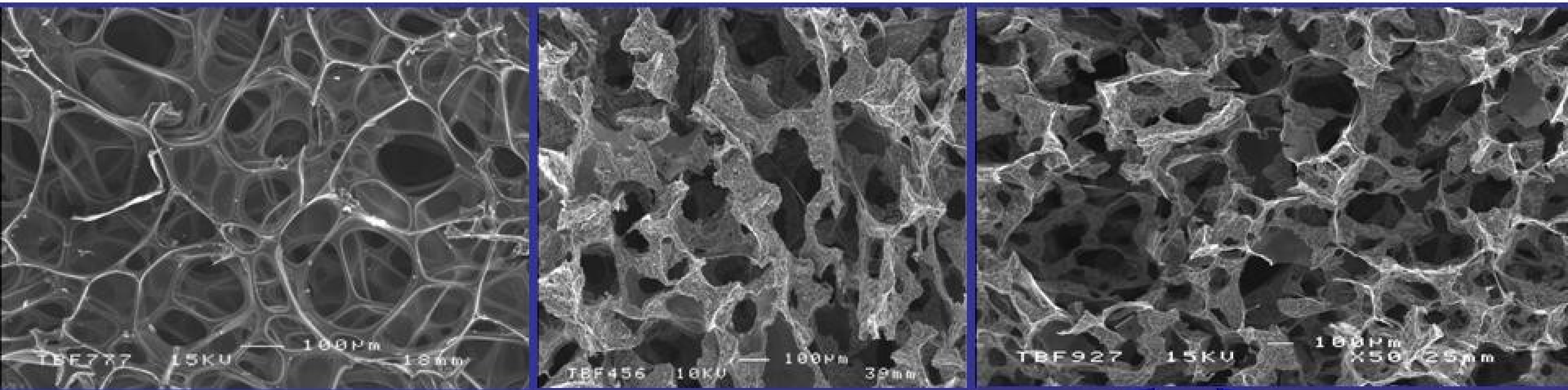




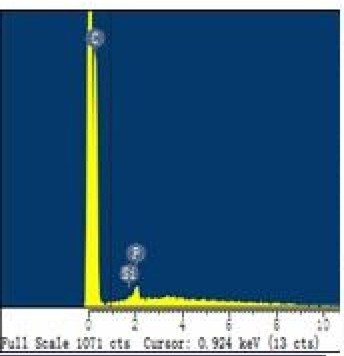
Carbon fibres

hierarchically porous carbon structures a

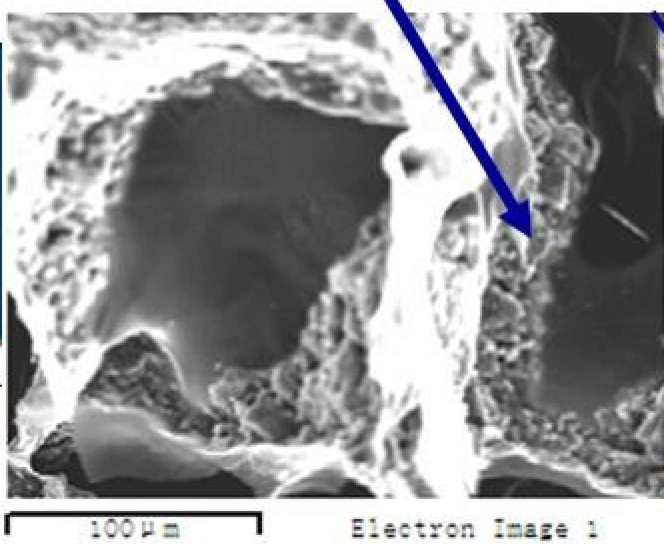
Various open-cell porous carbon structures can be tailored by composition & processing conditions

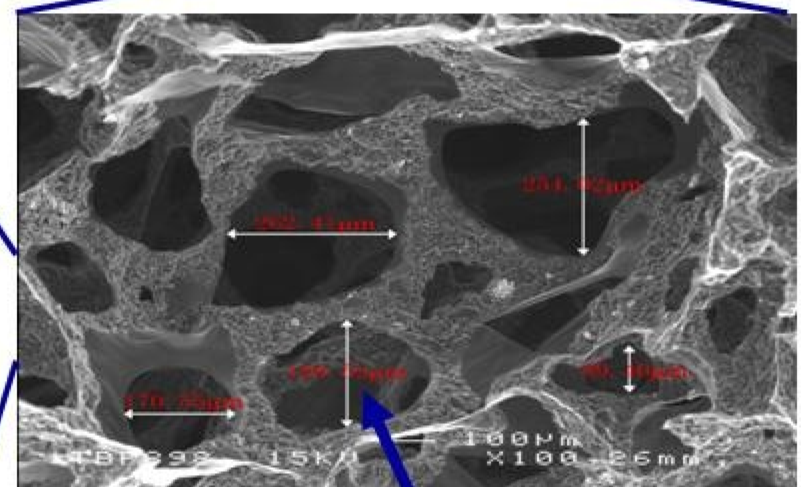


Meso-pores on carbon ridges to immobilize enzymes/catalysts



EDX Spectrum





Micro-pores to enhance electrode / molecule contact & electron transfer

Functionalised Porous Hybrids

Carbon, Li-SiO_2, Zeolites, Carbides - with Organic Linkers (-NH_2, -COOH)

TGA / DTA / DSC / P-C-I / MS / GC

XRD / EDX / SEM / TEM

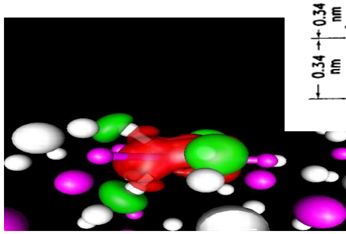
SPM / XPS / FT-IR

Chemical treatment, Self-Assembly, & Mineralisation

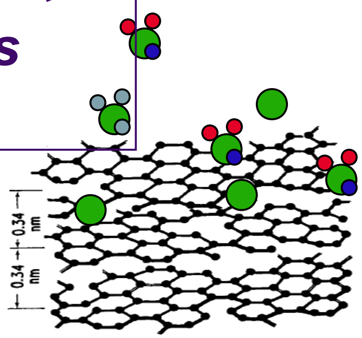
Hydrothermal / MA Synthesis - micropores

Templating - meso-pores

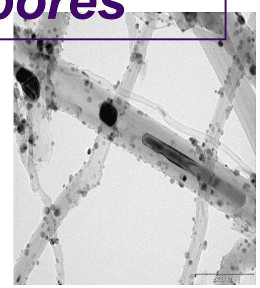
Foaming Free-forming, & sintering - macro-pores



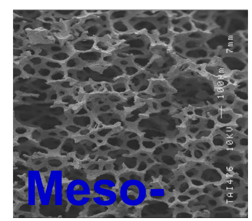
Bond Design



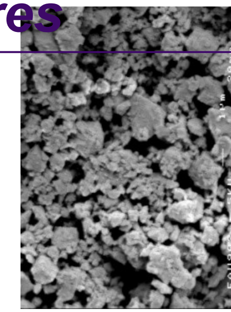
Molecular anchoring



Nano-catalysis



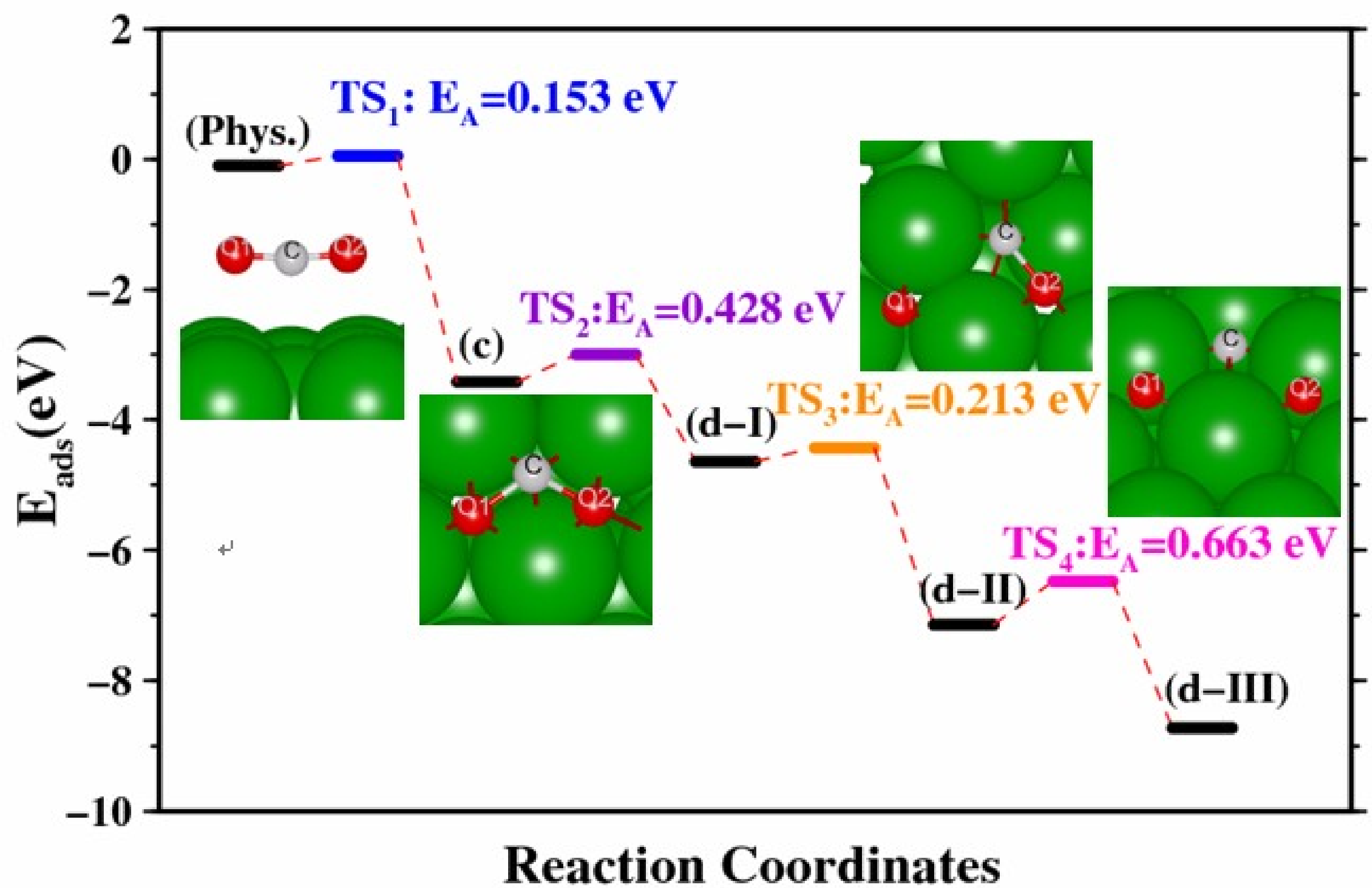
Meso-hybrid



Macro-support

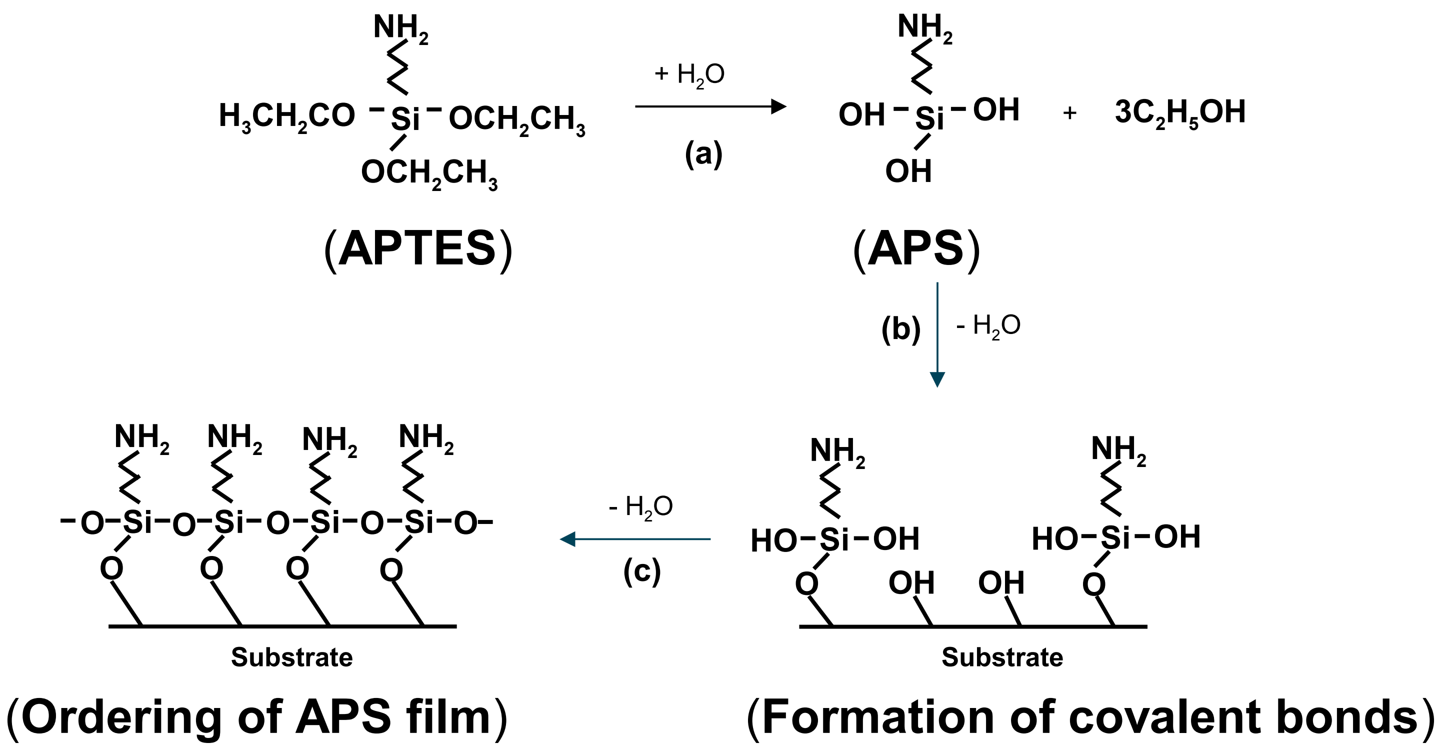
Ab Initio → QM/MM → QM/FEM → Flow-3D

Catalytic CO_2 Activation & Sorption



Li and Guo, JPCC, 2010, 114, 11456

Molecular self-assembly



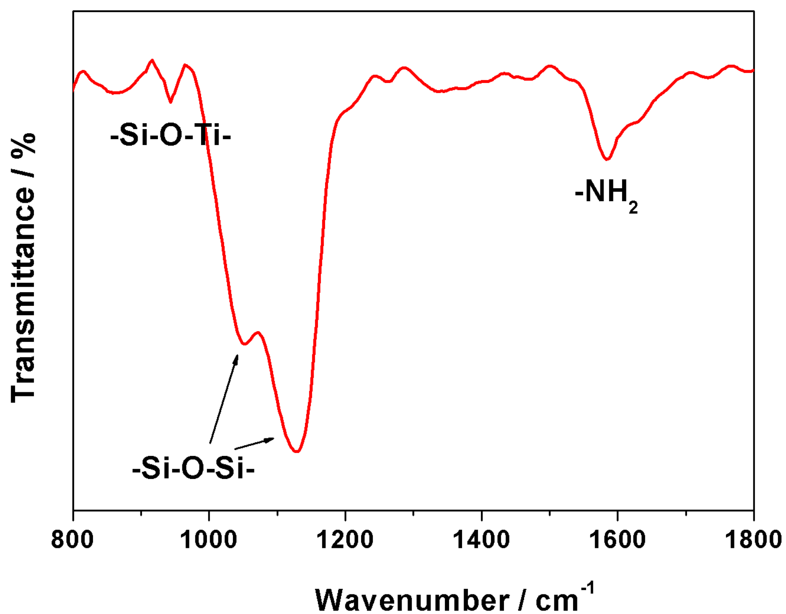
How to form a well-ordered film on substrate?

Confirmation of APS Film on Titanium (Ti) Surface

Polished titanium

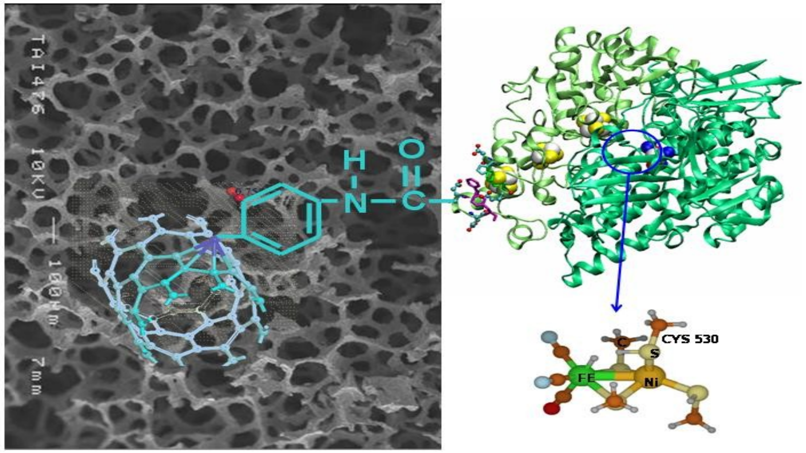
Oxidized titanium

Titanium with APS film

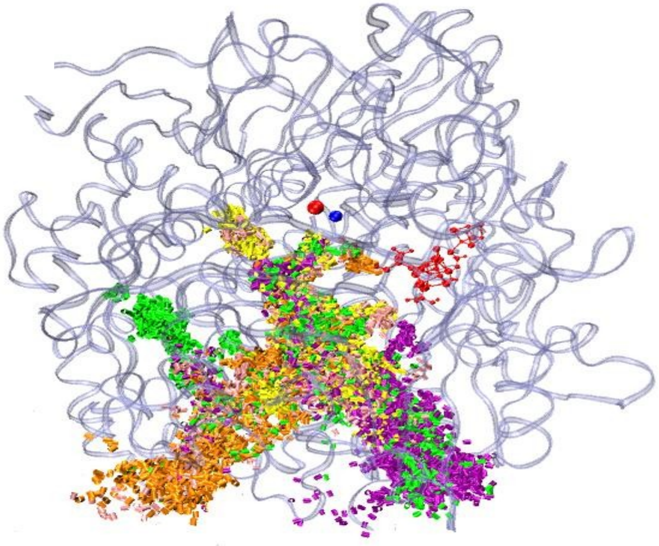


Based on oxidized titanium as background, IR spectrum on left confirms that the APS film has successfully assembled on the titanium surface.

Biofuel Cell Electrode Structures & H_2 Pathways

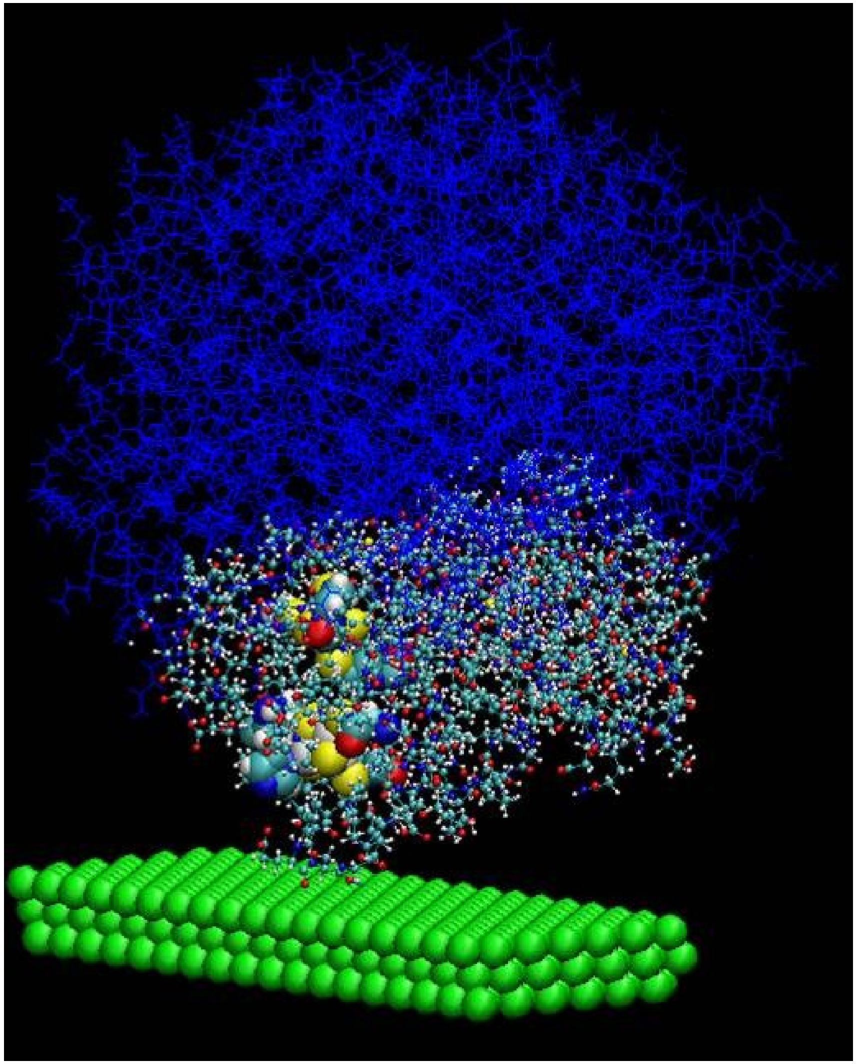


b)



Immobilisation of catalytic Enzymes onto porous electrode structures to enhance electron transfer and electrocatalysis.

Trajectories of H_2 to the active site with different colours indicating different H_2 molecules

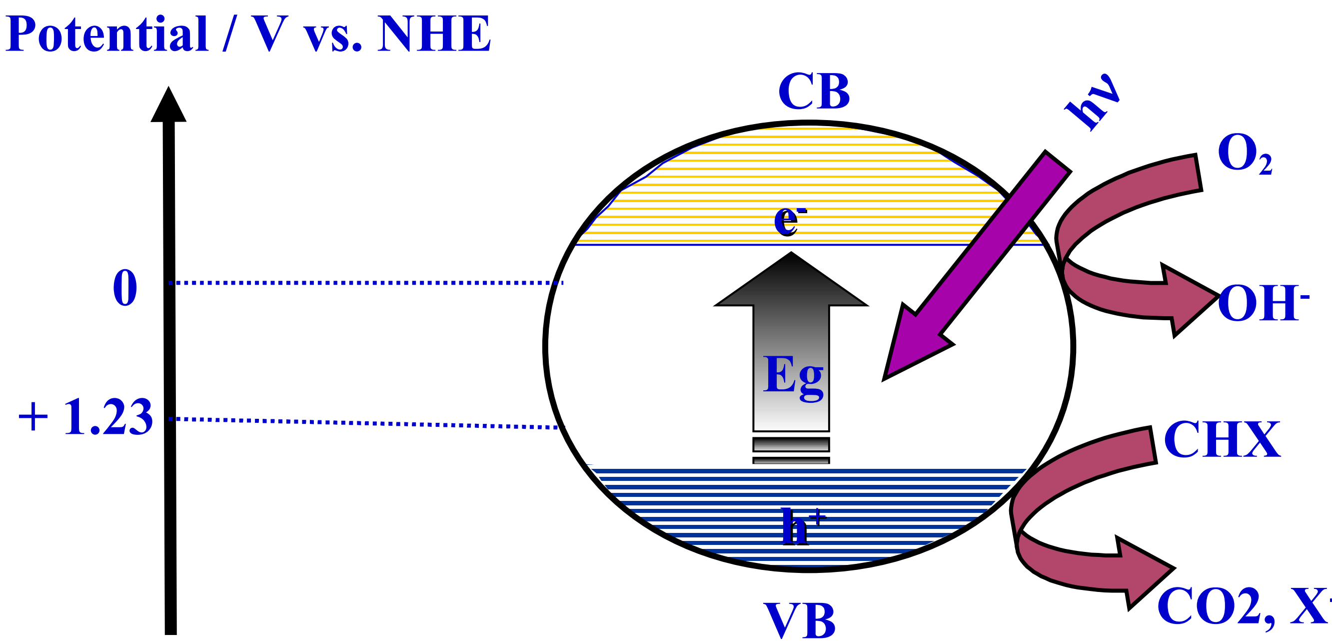


Photocatalytic purification of water

Junwang Tang

(Chem Eng)

Photocatalytic purification of water



Requisites:

1) Light irradiation
2) Semiconductor photocatalyst

Advantages:

1) Friendly to environment;

2) Economical.

Materials (1) Suitable Band gap

(2) Appropriate VB and CB potentials.

Efficiency: Charge transfer and separation (Dynamics)

Dye contaminants

Methylene Blue (MB) degradation

Under UV: Many results.

Under visible light: T. Asahi et al $TiO_{2-x}N_x$[1] ;

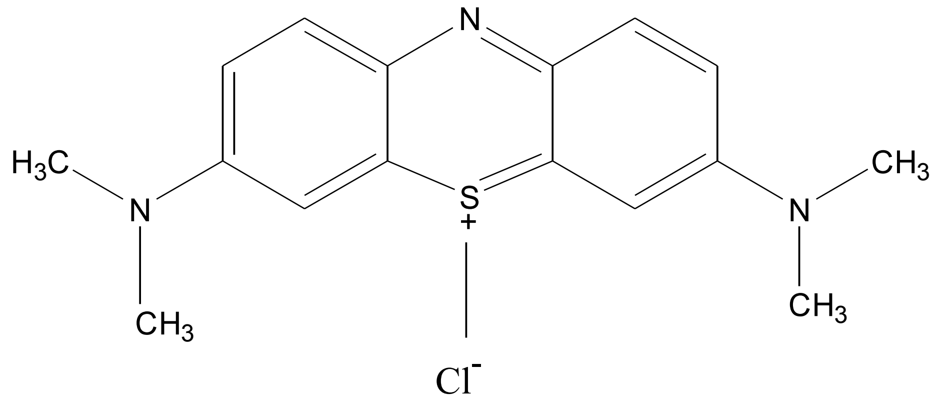
Our results MIn_2O_4

Synthesis Method: Solid-state reaction method

Semiconductor: MIn_2O_4 (M = Ca, Sr, Ba)

Original Materials: MCO_3 (M = Ca, Sr, Ba) and In_2O_3

MB degradation



Visible light

Semiconductor photocatalyst

MIn_2O_4 (M = Ca, Sr, Ba)

SO_4^{2-}, NO_3^-, CO_2, H_2O

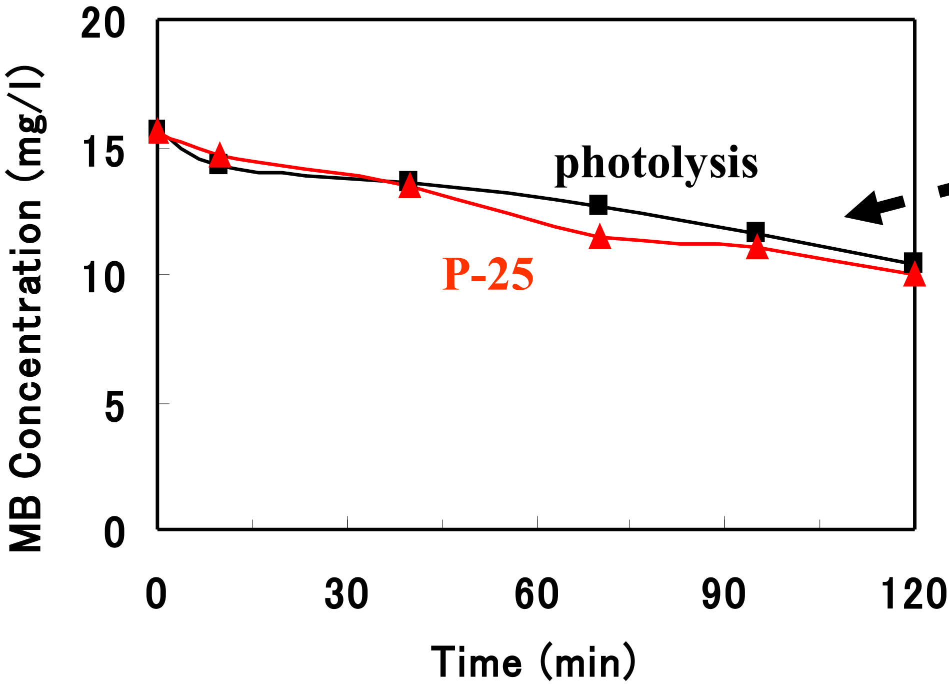
Reaction

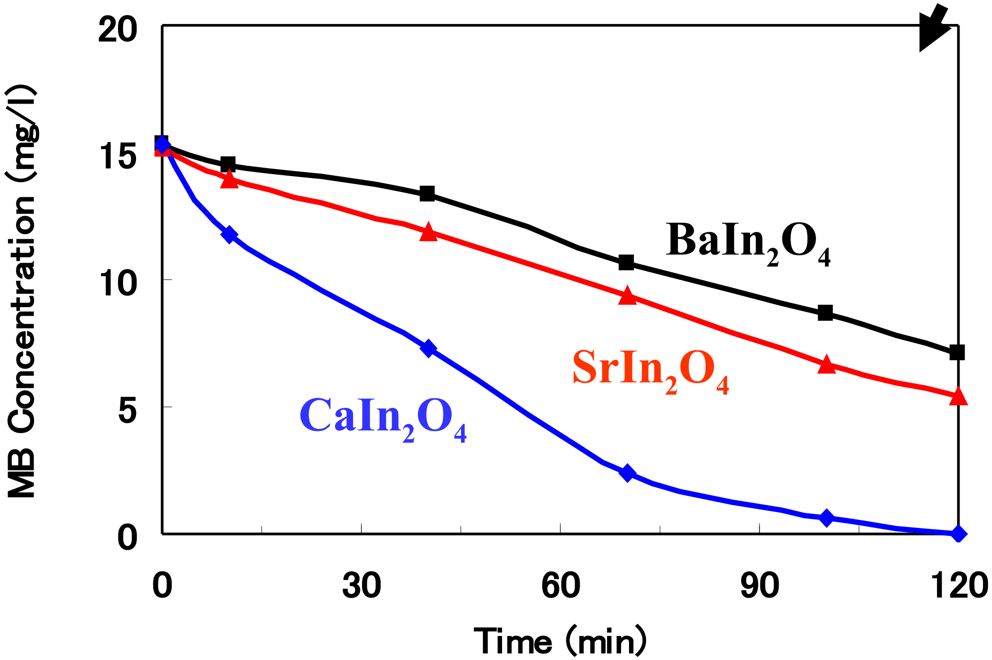
a 300 W Xe arc lamp, a cut-off filter and a water filter

0.3 g powdered MIn_2O_4 (M = Ca, Sr, Ba) photocatalysts

or P-25 suspended in 100 ml MB solution at room temperature in air.

MB Photolysis and Degradation under visible light (λ > 420nm) in air.





Photocatalyst	Surface area (m^2/g)	MB adsorption (mg MB / g catalyst)	SO_4^{2-} yield (%)
P-25	49.41	more than 1.0	0
$CaIn_2O_4$	0.86	0.4	60
$SrIn_2O_4$	0.84		42
$BaIn_2O_4$	0.79		30

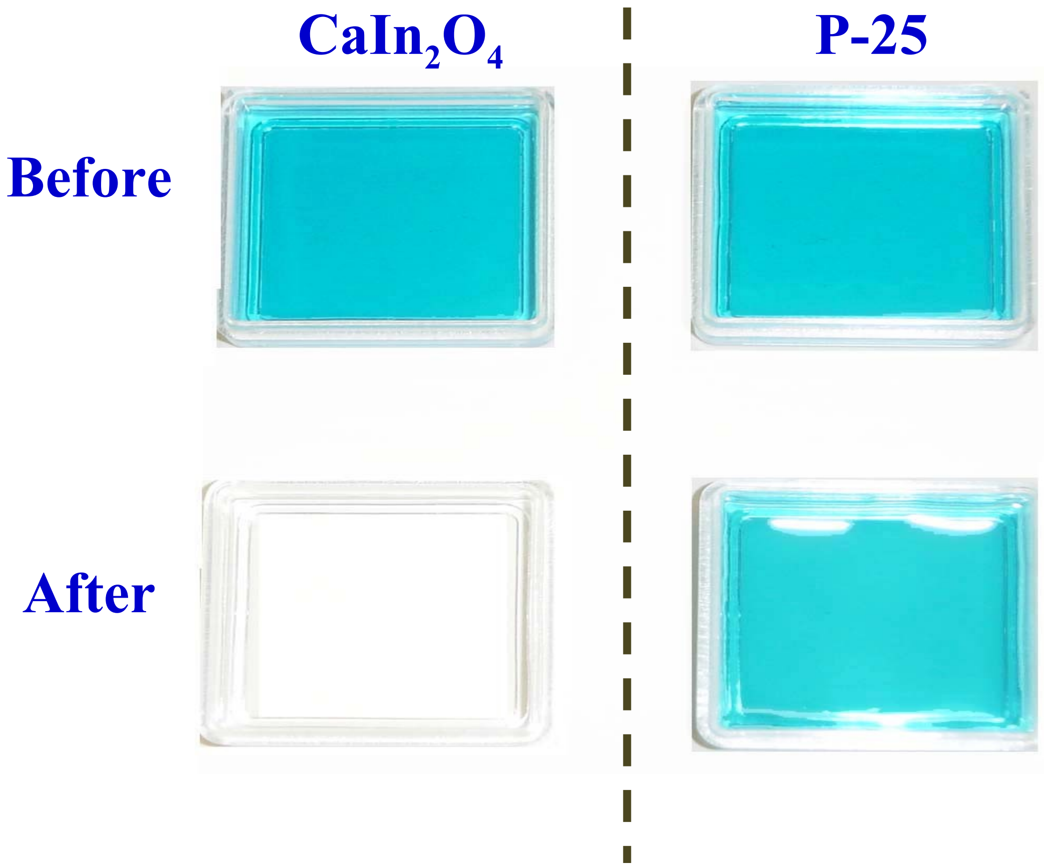
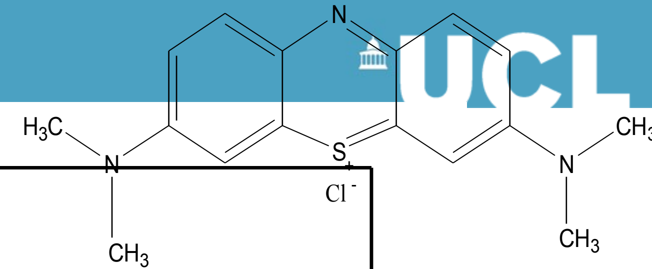


Fig. Photos of the solution before and after 2 hour photocatalytic reaction under visible light ($\lambda > 420$nm).



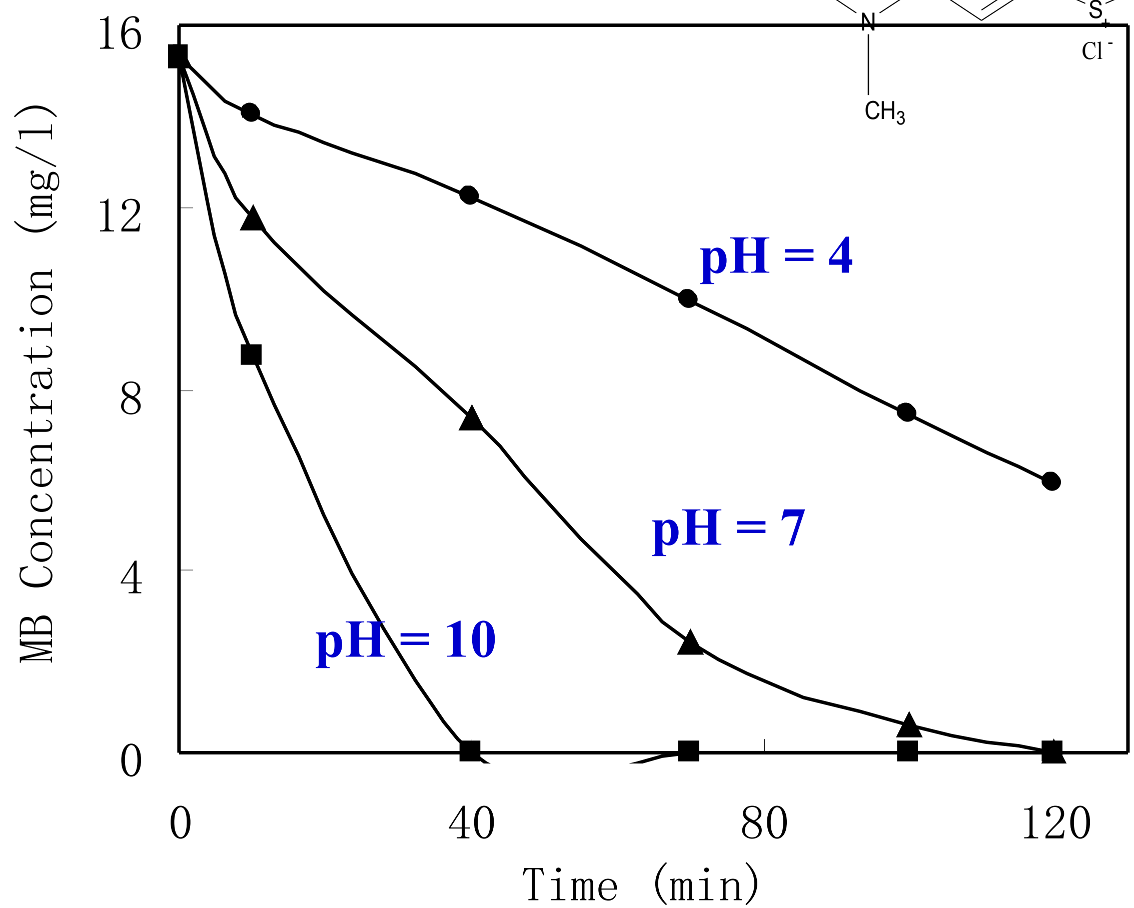


Fig. Effect of pH value on MB degradation over $CaIn_2O_4$ photocatalyst under visible light (λ > 420 nm).

Thank You

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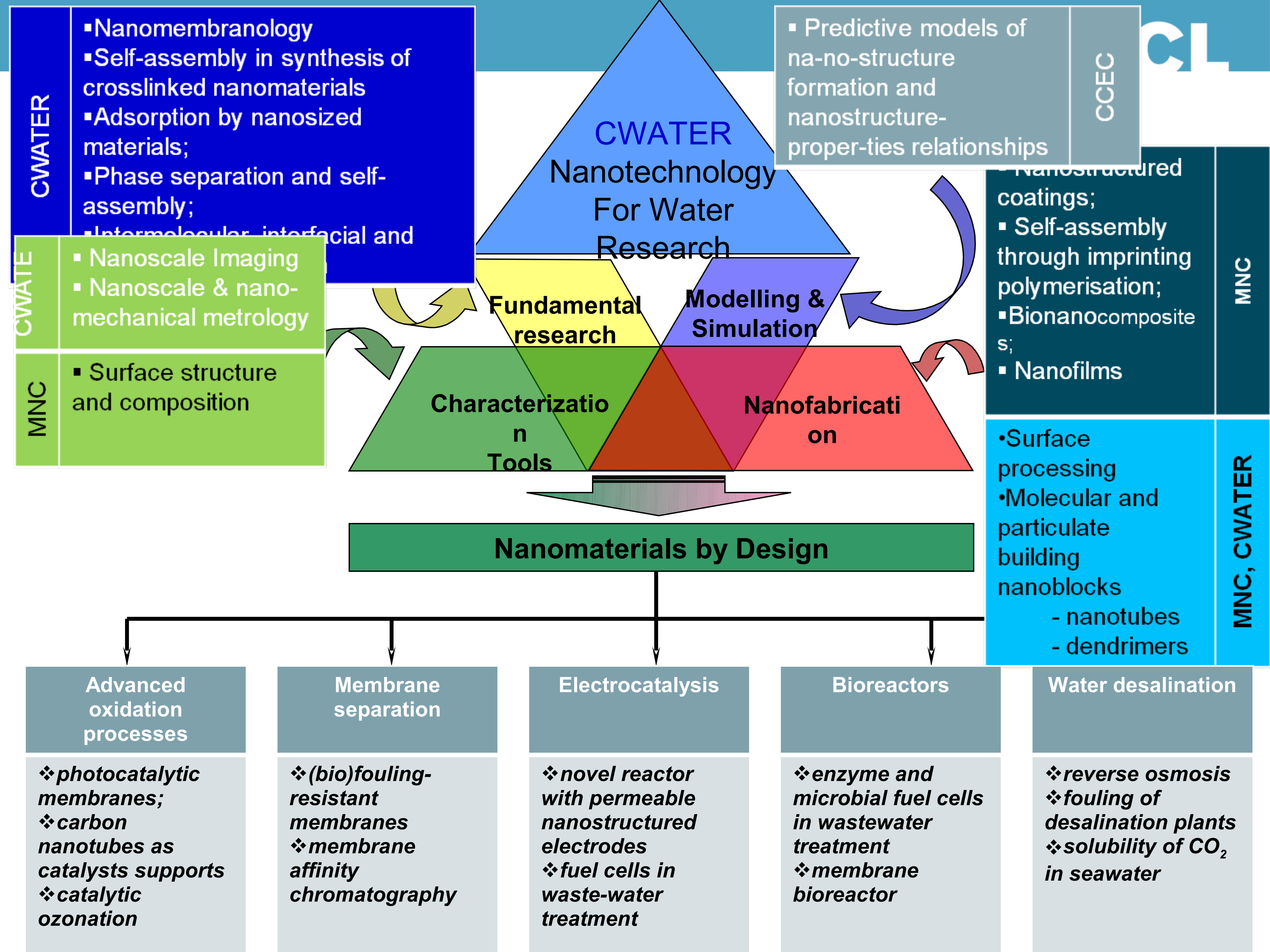
Centre for Water Advanced Technologies and Environmental Research (C WATER)

Swansea University
United Kingdom

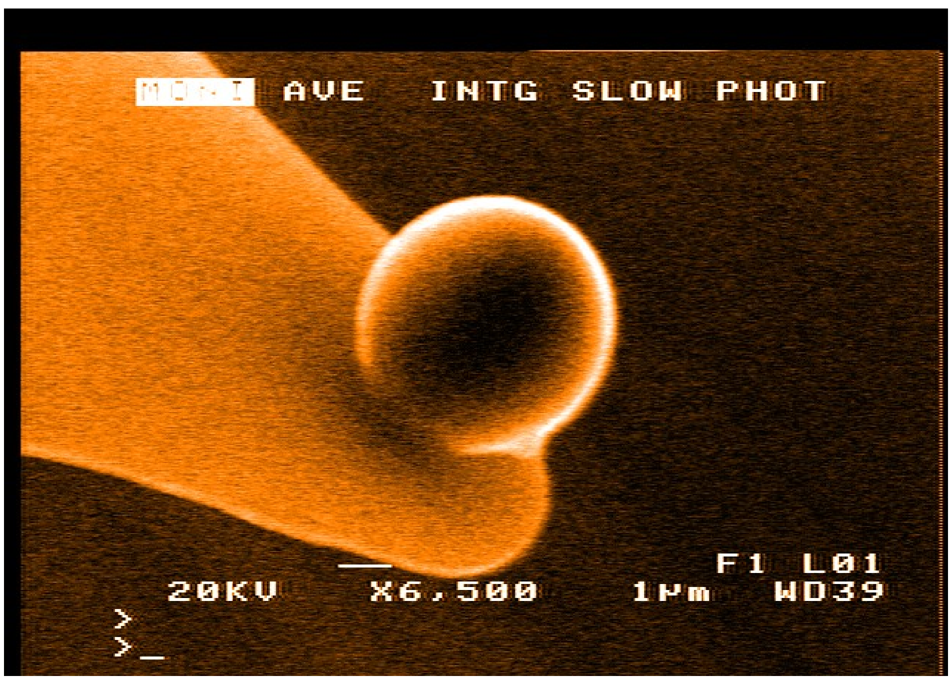
Professor Nidal Hilal
Dr Chedly Tizaoui

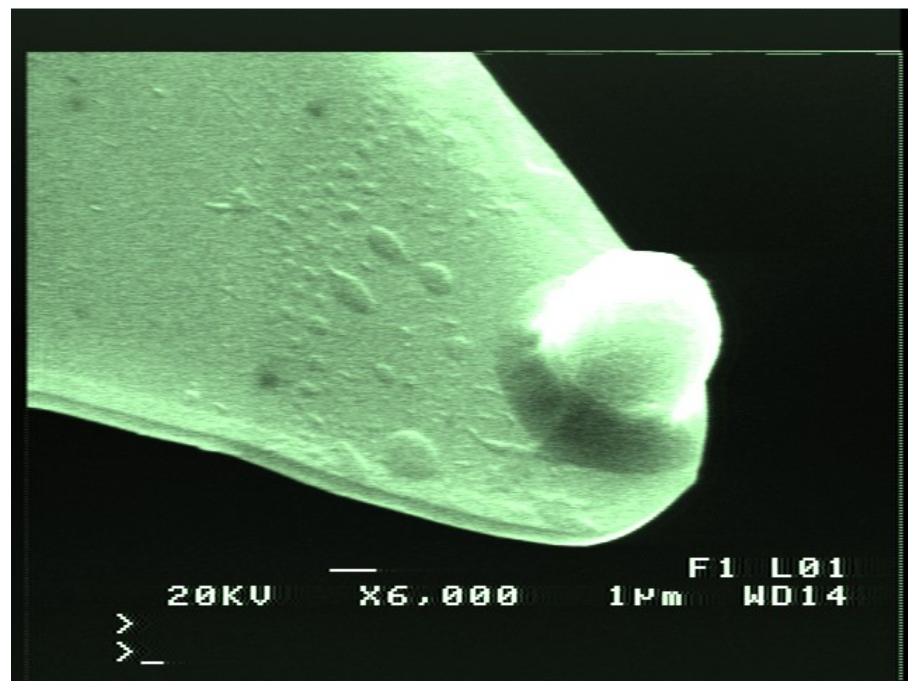

CWATER
▪Nanomembranology
▪Self-assembly in synthesis of crosslinked nanomaterials
▪Adsorption by nanosized materials;
▪Phase separation and self-assembly;
CWATE
▪ Nanoscale Imaging
▪ Nanoscale & nano-mechanical metrology
MNC
▪ Surface structure and composition
CWATER
Nanotechnology
For Water
Research
▪ Predictive models of na-no-structure formation and nanostructure-proper-ties relationships
CCEC
coatings;
▪ Self-assembly through imprinting polymerisation;
▪Bionanocomposites;
▪ Nanofilms
MNC
•Surface processing
•Molecular and particulate building nanoblocks
- nanotubes
- dendrimers
MNC, CWATER
Fundamental research
Modelling & Simulation
Characterization Tools
Nanofabrication
Nanomaterials by Design
Advanced oxidation processes
❖photocatalytic membranes;
❖carbon nanotubes as catalysts supports
❖catalytic ozonation
Membrane separation
❖(bio)fouling-resistant membranes
❖membrane affinity chromatography
Electrocatalysis
❖novel reactor with permeable nanostructured electrodes
❖fuel cells in waste-water treatment
Bioreactors
❖enzyme and microbial fuel cells in wastewater treatment
❖membrane bioreactor
Water desalination
❖reverse osmosis
❖fouling of desalination plants
❖solubility of CO_2 in seawater

Colloid and Cell Probe Techniques

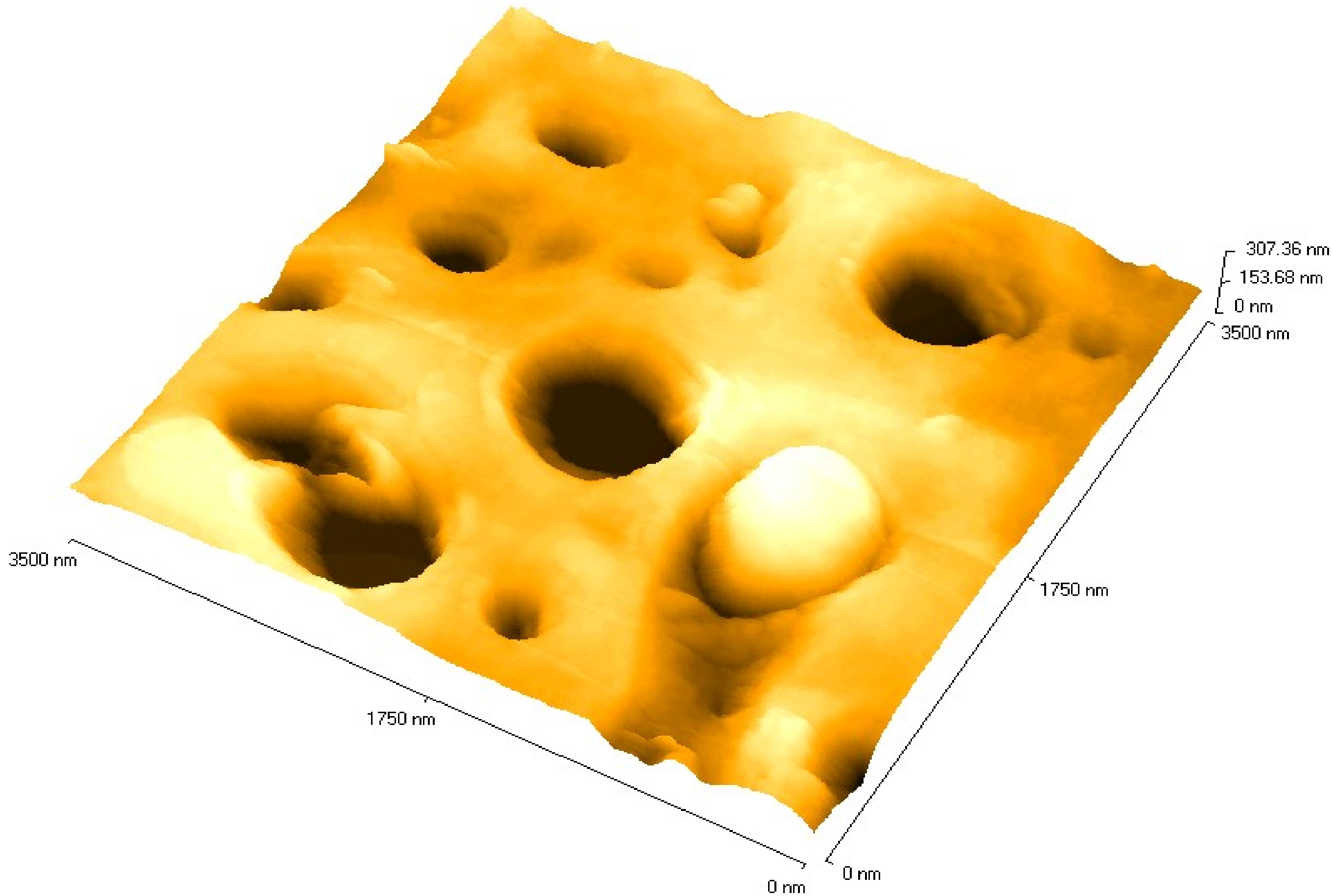
- Silicon dioxide sphere attached to the apex of AFM cantilever (colloid probe).

- Living yeast cell immobilised to the apex of AFM cantilever (cell probe).

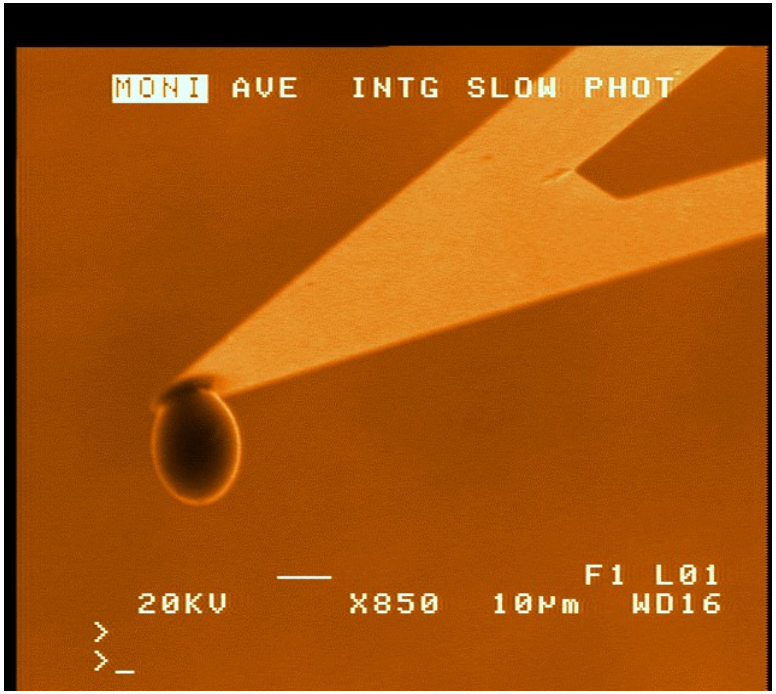




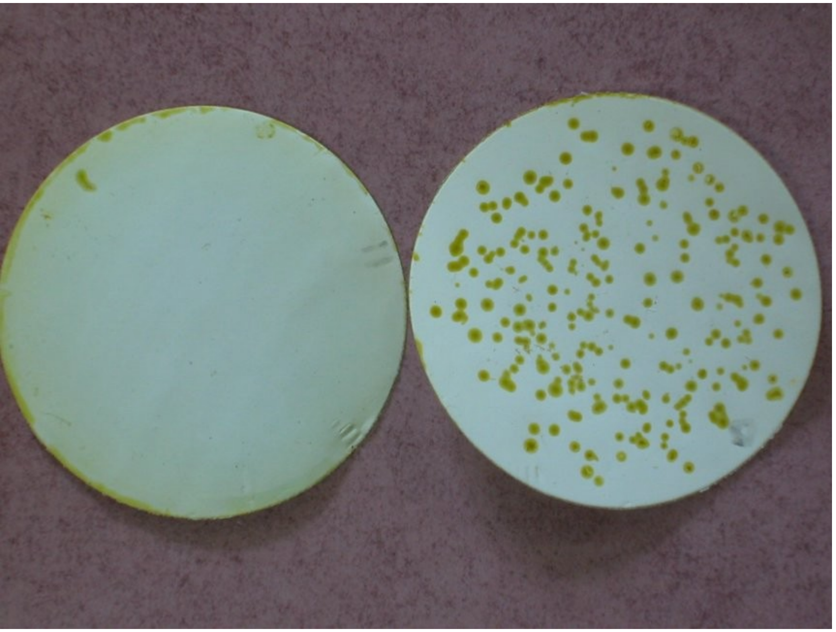
Atomic Force Microscopy image
Bio-colloid of 0.3 μm Blocking
MF Membrane Pore



AFM as a tool to assess surface adhesion (membrane fouling)

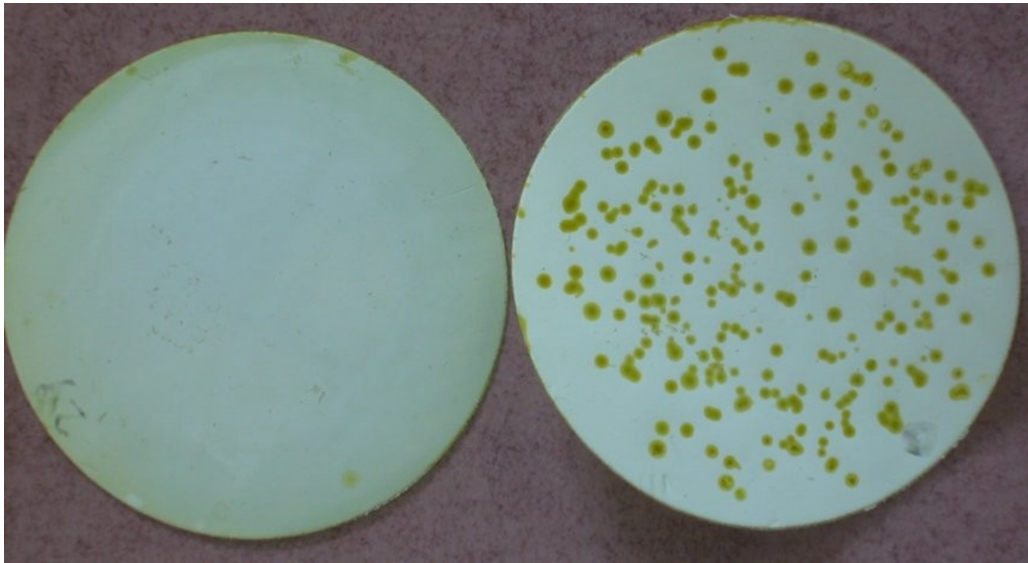


Development of (bio)fouling resistant membranes

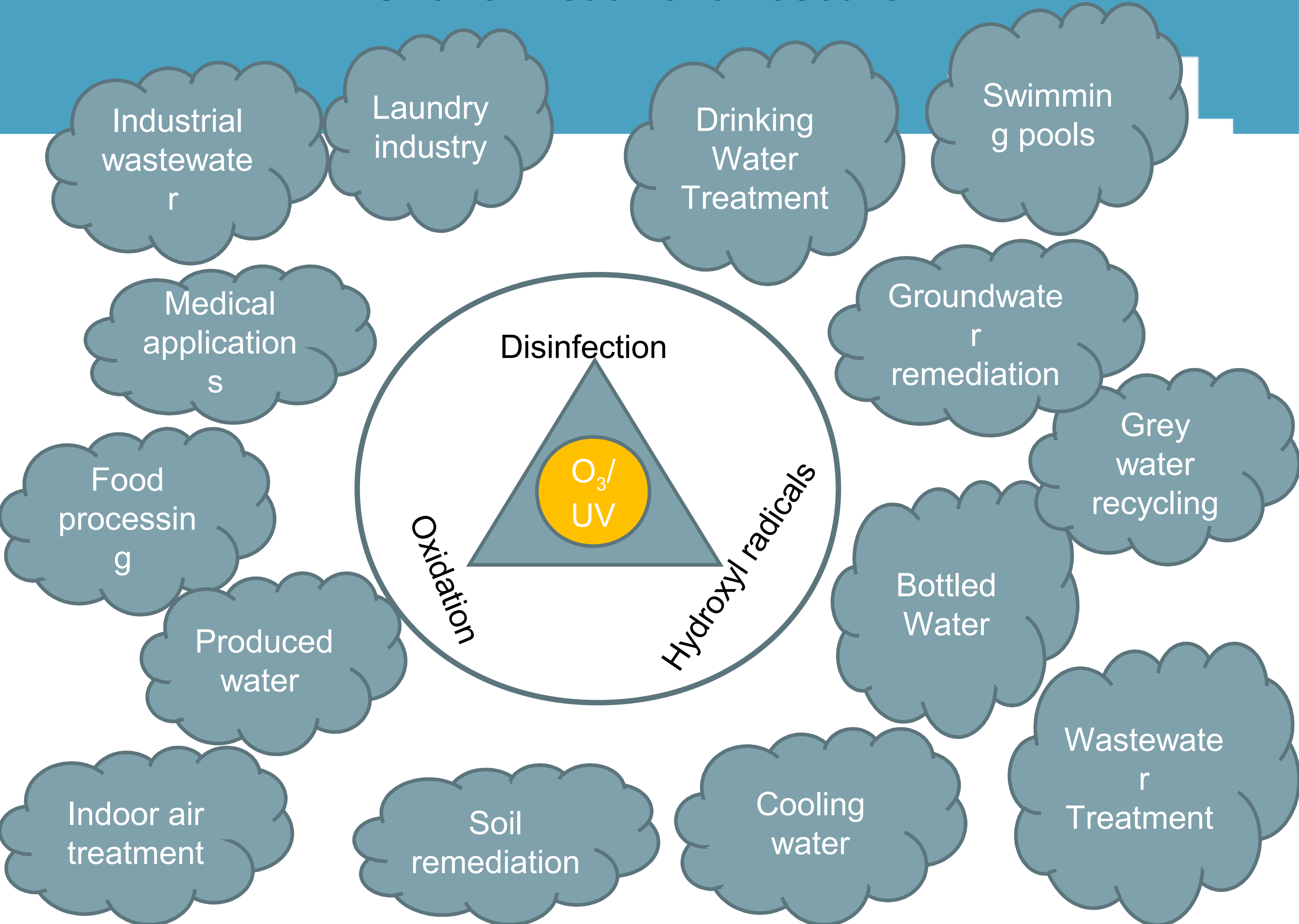


Photograph of initial PVDF(left),
& PVDF modified membranes

Photograph of initial PES (right),
& PES modified membranes



Ozone Treatment Research



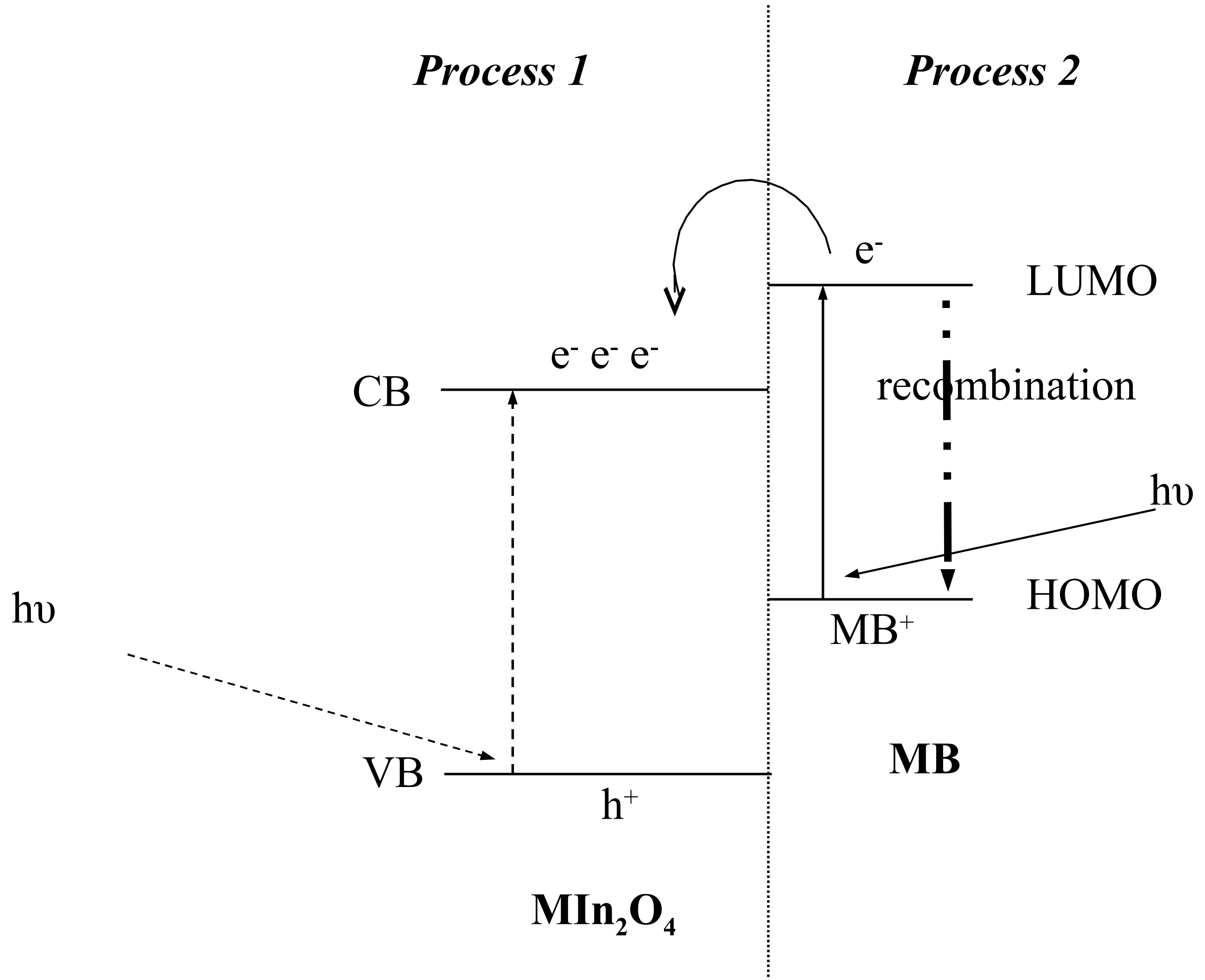


Fig. 12. Sketch diagram of photogenerated electrons transition under visible light between MIn_2O_4 photocatalysts and MB.