EPSNA

THE ETHIOPIAN PHYSICS SOCIETY IN NORTH AMERICA

Nanostructured Materials and How to Modify Nanostructured Materials' Property for a Particular Application

Virtual Summer School@ASTU

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Content

1. Nanostructured materials
2. Modification of nanostructured material
3. Analysis the efficiency of nanostructured material
4. Target
5. Conclusion

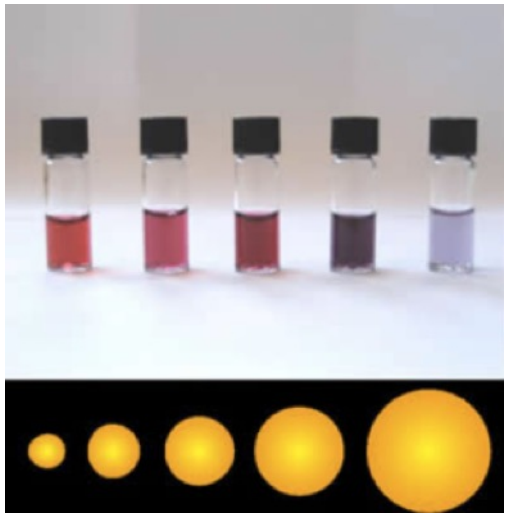
1. Nanostructured Materials

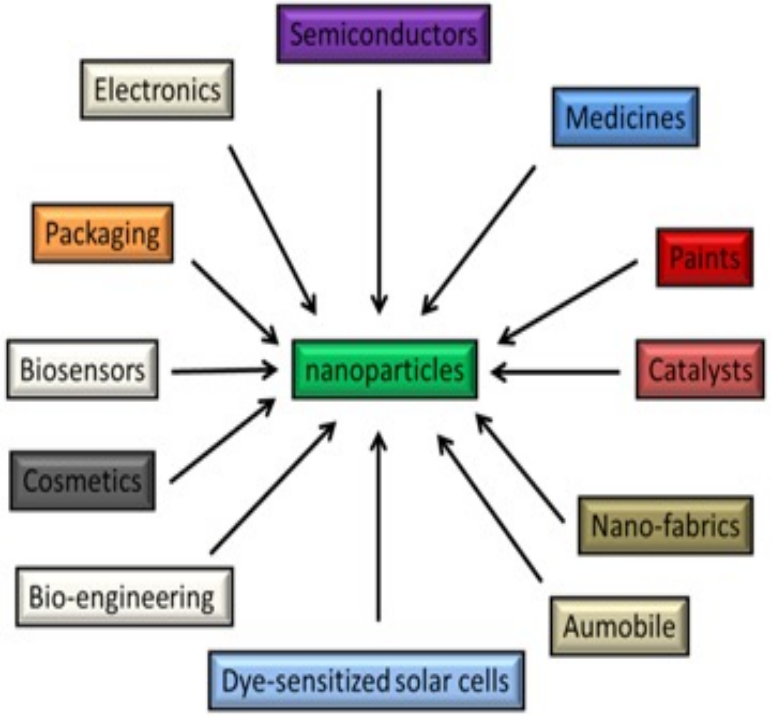
☞Currently Researchers have gained great attention to fabricate

- different properties
- various applications

Nano scale materials (1-100 nm)

- Arranged into layers
- Large surface area
- Enhanced Activity





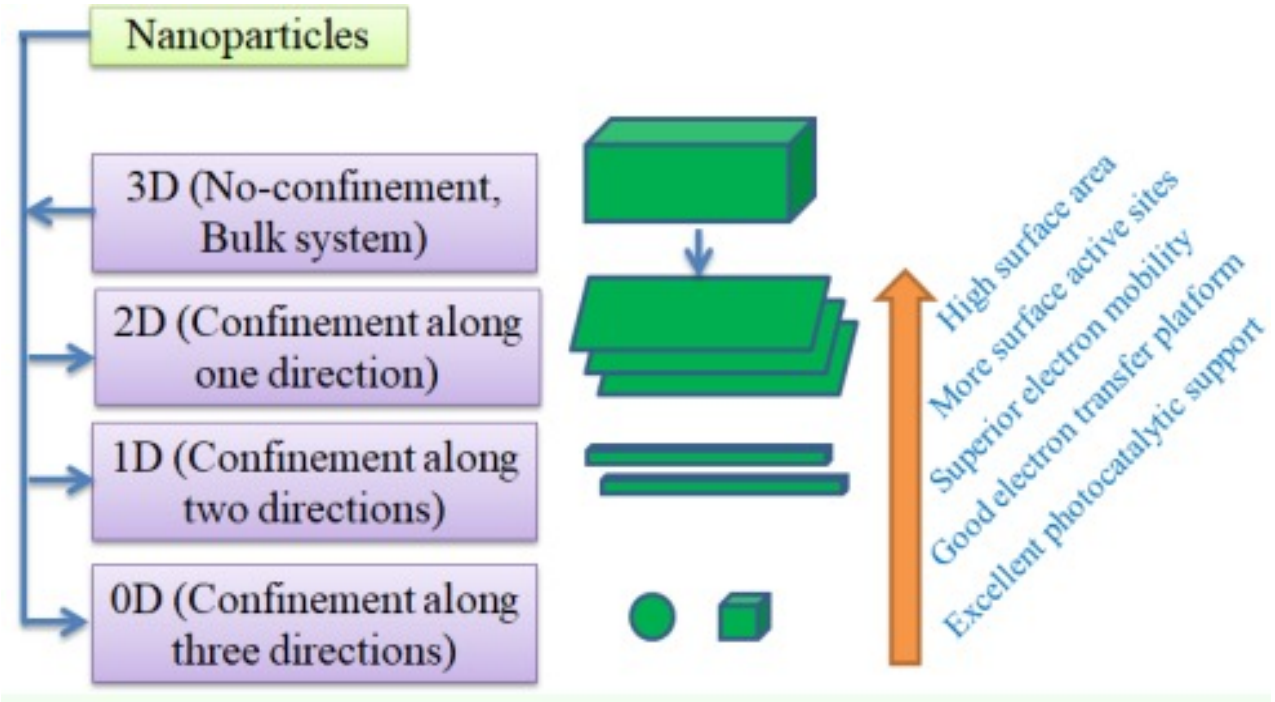
1. Nanostructured Materials (Cont'd)

☞Nanoparticles

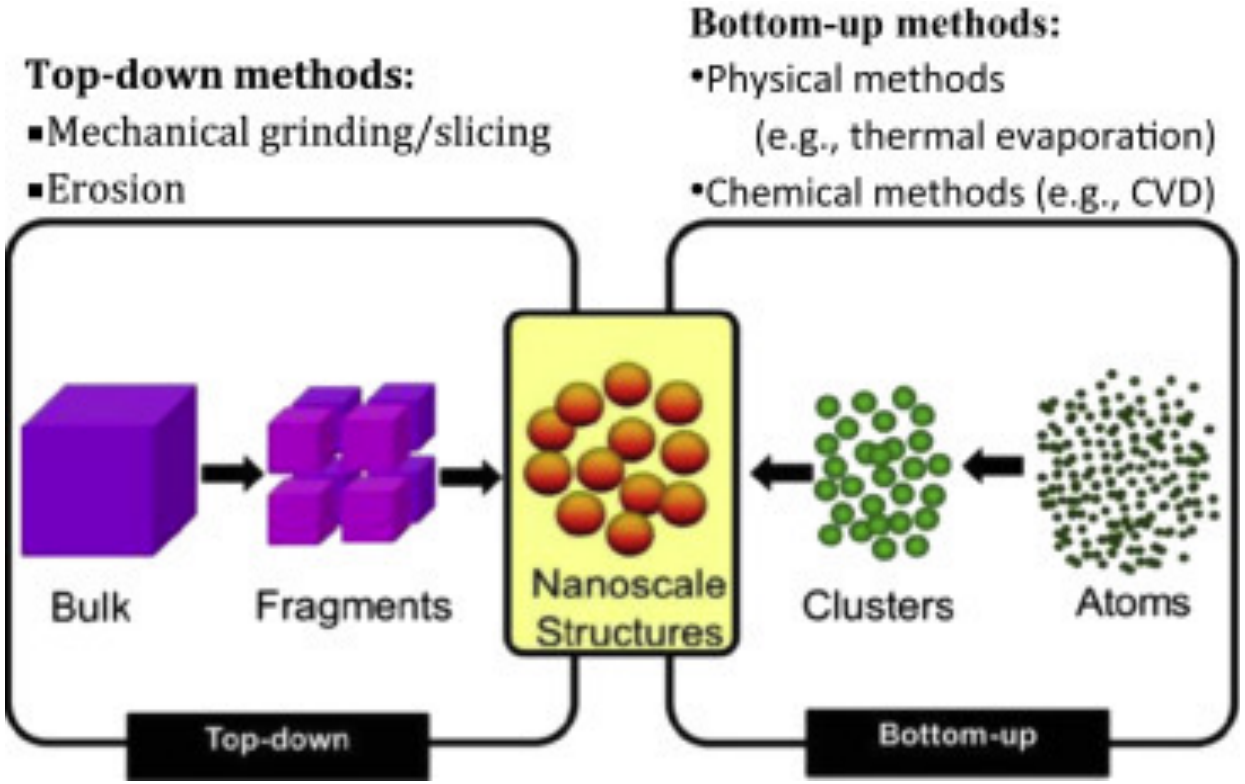
limitations
(drawbacks)

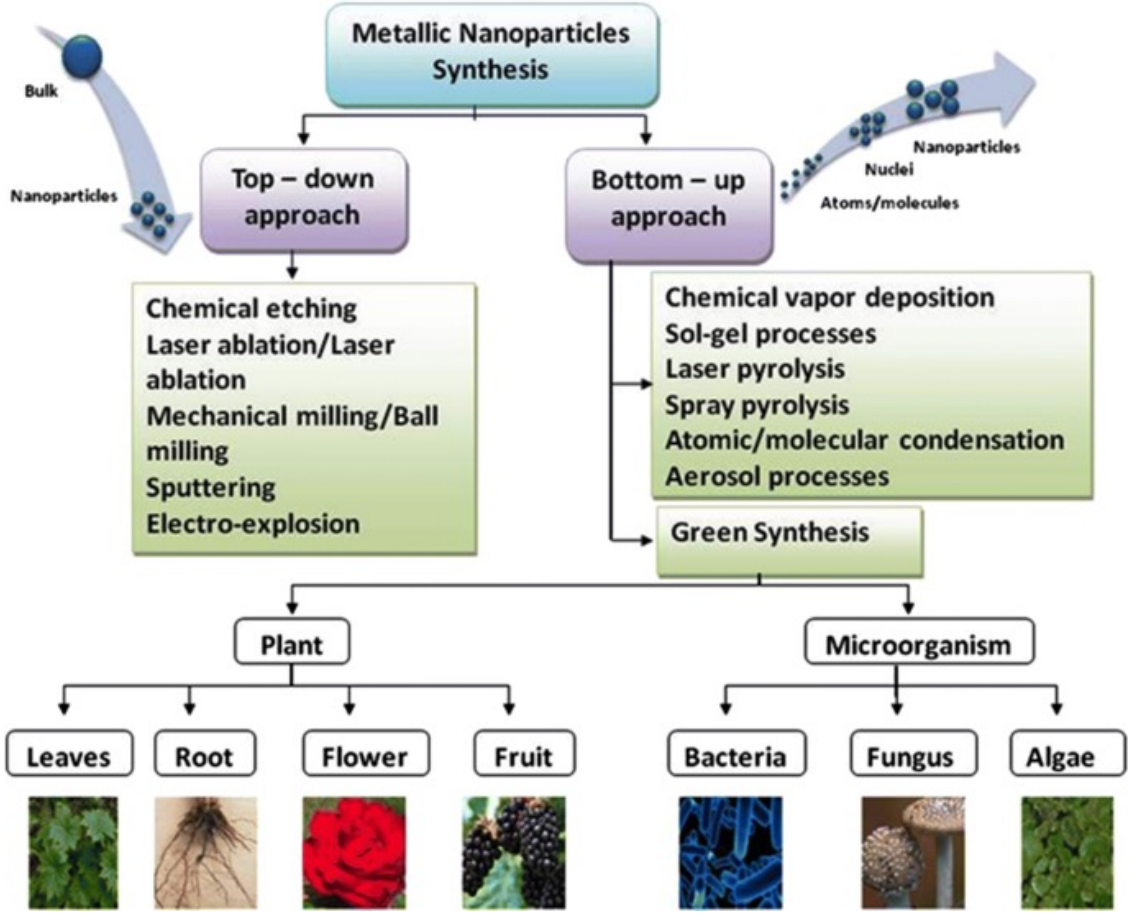
- Metal
- Oxide
- Organic/inorganic
- MOFs

- Band gap energy
- Recombination rate of $e^- - h^+$
- Morphology
- Surface interaction or active site
- Re-usability/recyclability
- Chemical/thermal stability

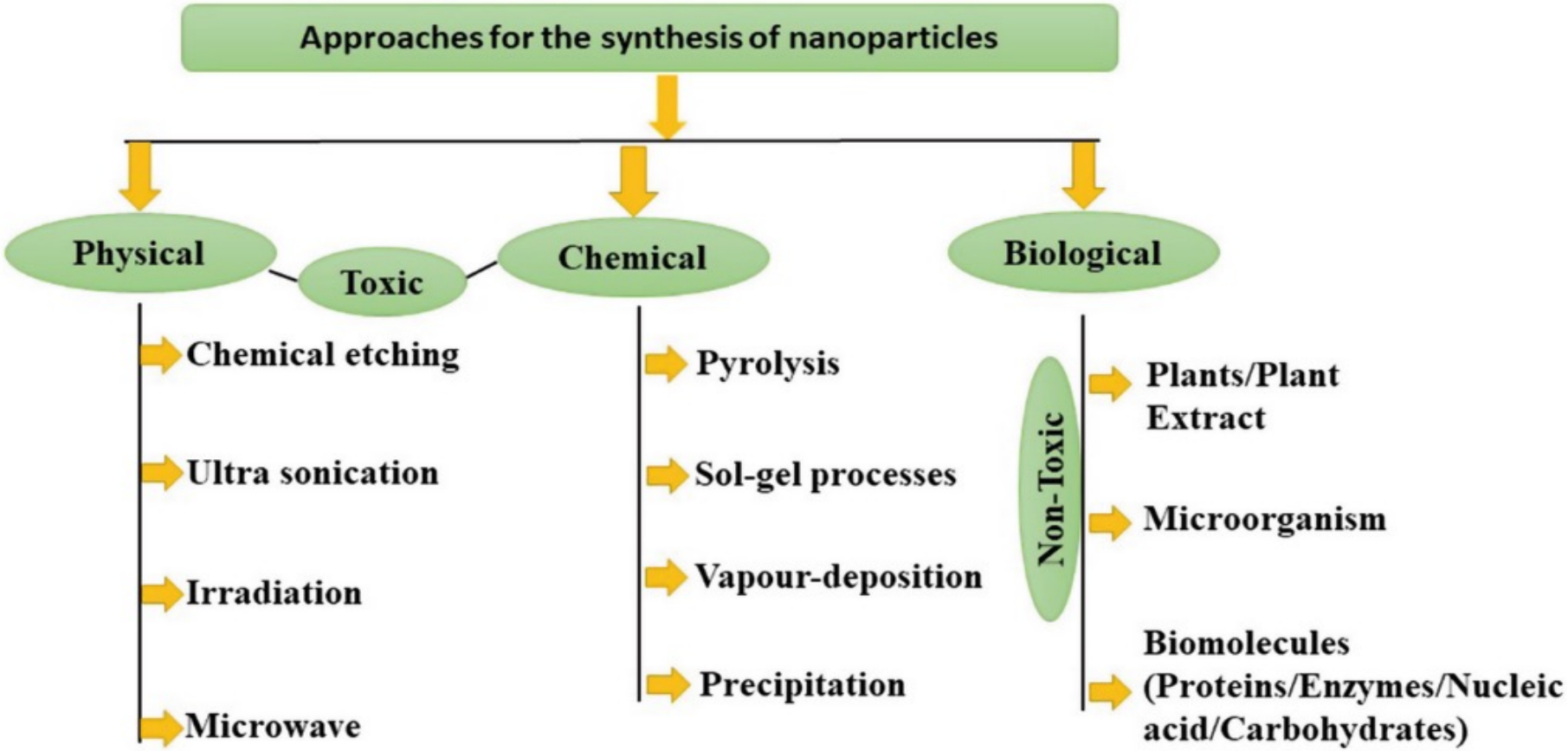


❖ Synthesis of Nanoparticles

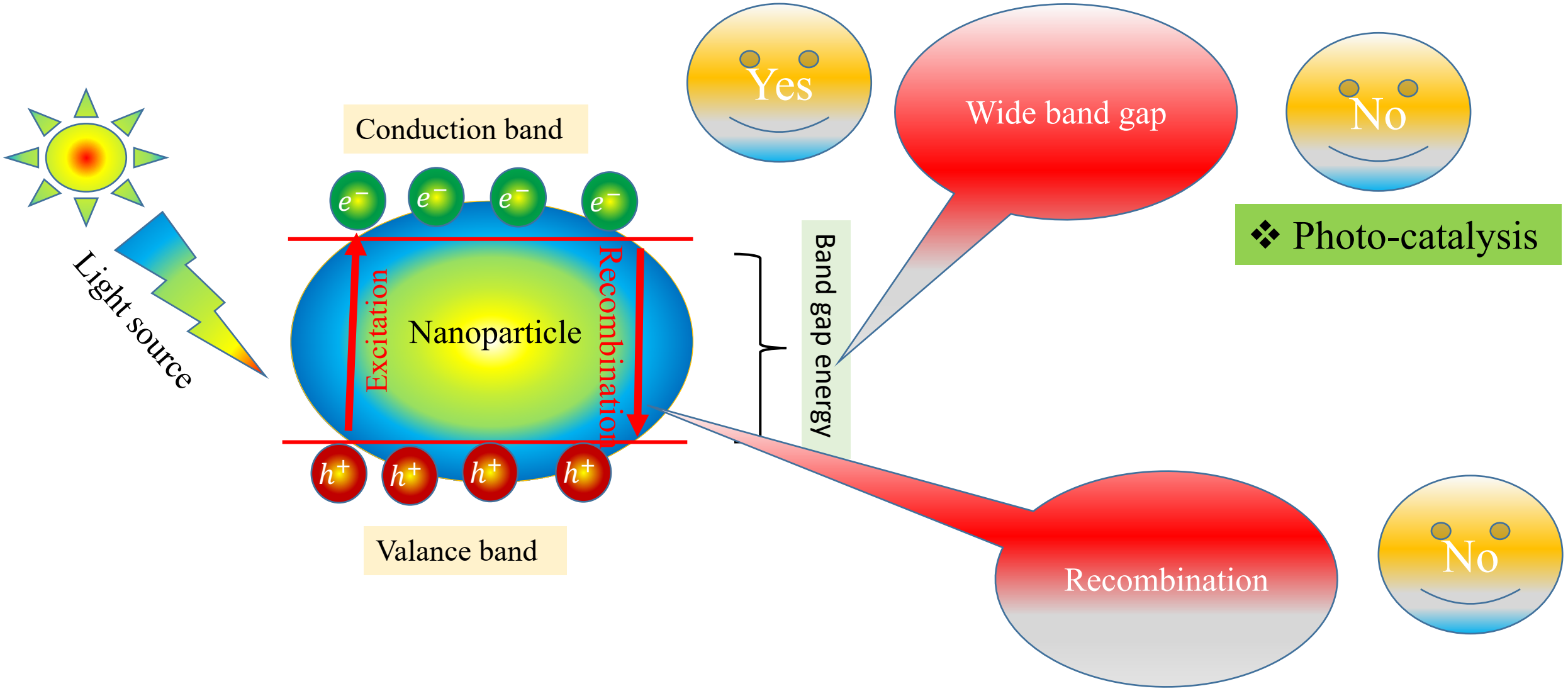




1. Nanostructured Materials (Cont'd)

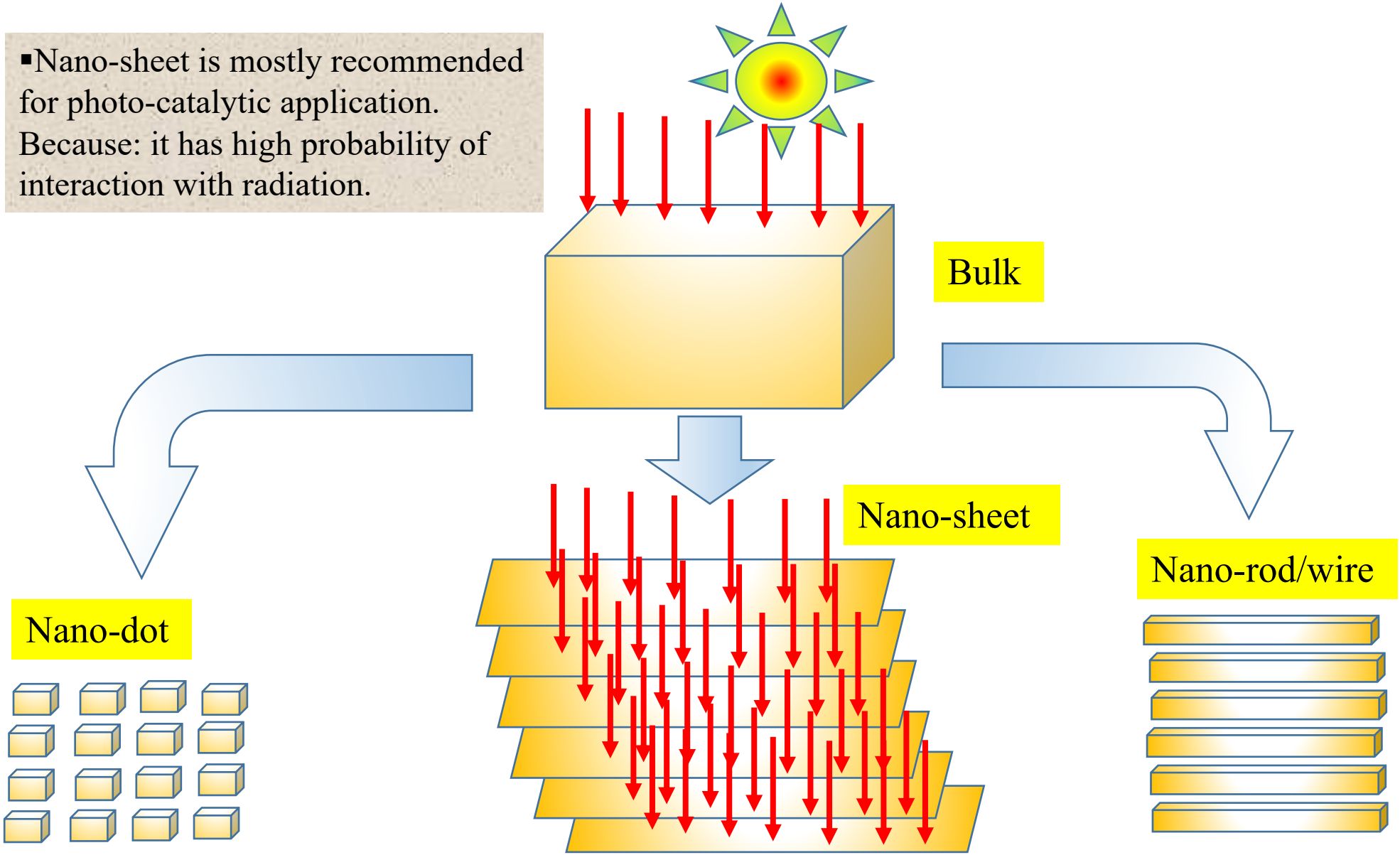


1. Nanostructured Materials (Cont'd)

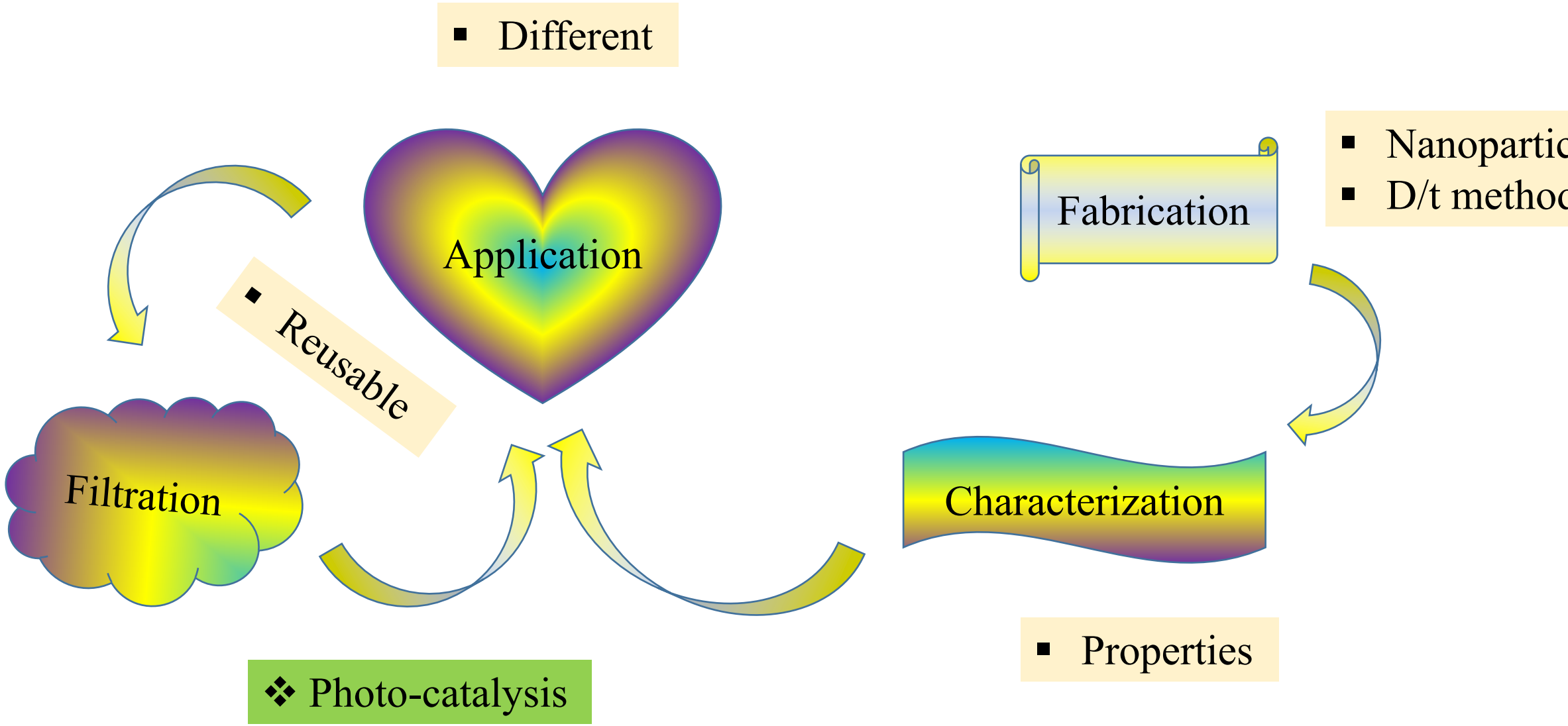


1. Nanostructured Materials (Cont'd)

▪Nano-sheet is mostly recommended for photo-catalytic application.
Because: it has high probability of interaction with radiation.



1. Nanostructured Materials (Cont'd)



1. Nanostructured Materials (Cont'd)

- The synthesized sample will characterize by using different characterization techniques

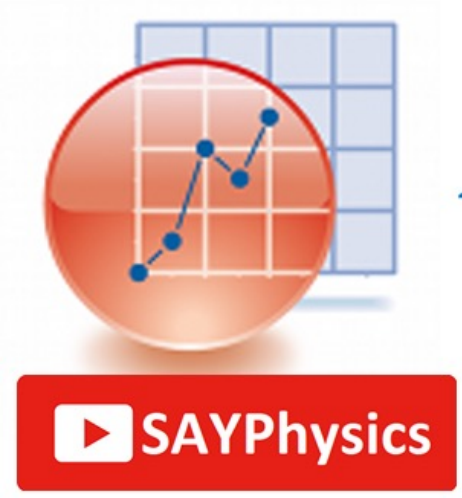
Techniques	Parameters	Properties that are analyzed
Dynamic light scattering	Hydrodynamic radius	Nanoparticle size, size distribution, and zeta potential analysis
Photon correlation spectroscopy	Velocity distribution by measuring the dynamic fluctuation of scattered light	Nanoparticle average size, polydispersity index analysis, etcetera
X-ray diffraction analysis	Diffraction pattern	Phase identification, nanoparticle structure, size, lattice parameters
X-ray photoelectron spectroscopy	Binding energy of the detected electrons	Nanoparticle composition, uniformity of composition
Laser doppler anemometry	Frequency shift and phase shift	Zeta potential and particle composition
Thermogravimetric analysis	Temperature and time as a function in mass change	Kinetic parameters, physical and chemical properties
Transmission/scanning electron microscopy	Electron scattering	Morphology of particles, distribution of particles

- ✓ UV-Vis spectroscopy (optical properties, band gap energy, photocatalytic response)
- ✓ FT-IR spectroscope (constituents and possible bonds)
- ✓ PL spectroscope (photoluminescence properties)

❖XRD

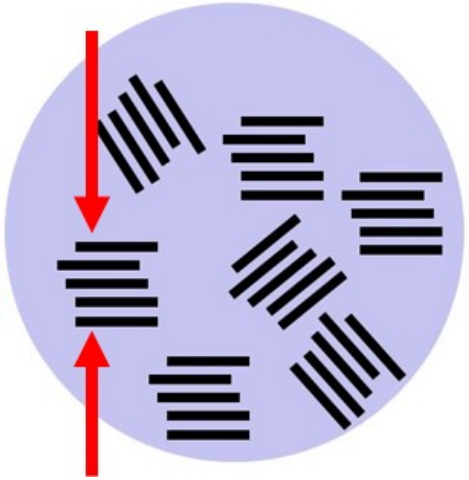
Crystallite Size from XRD data

- β = FWHM in radians
- θ is location peak

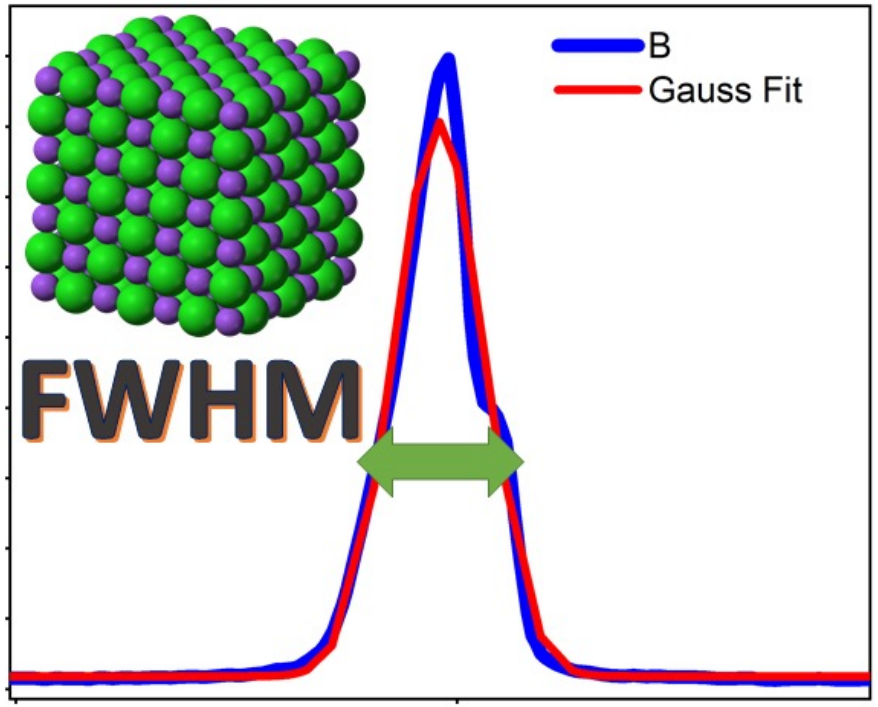


SAYPhysics

$$D = \frac{K\lambda}{\beta \cos\theta}$$

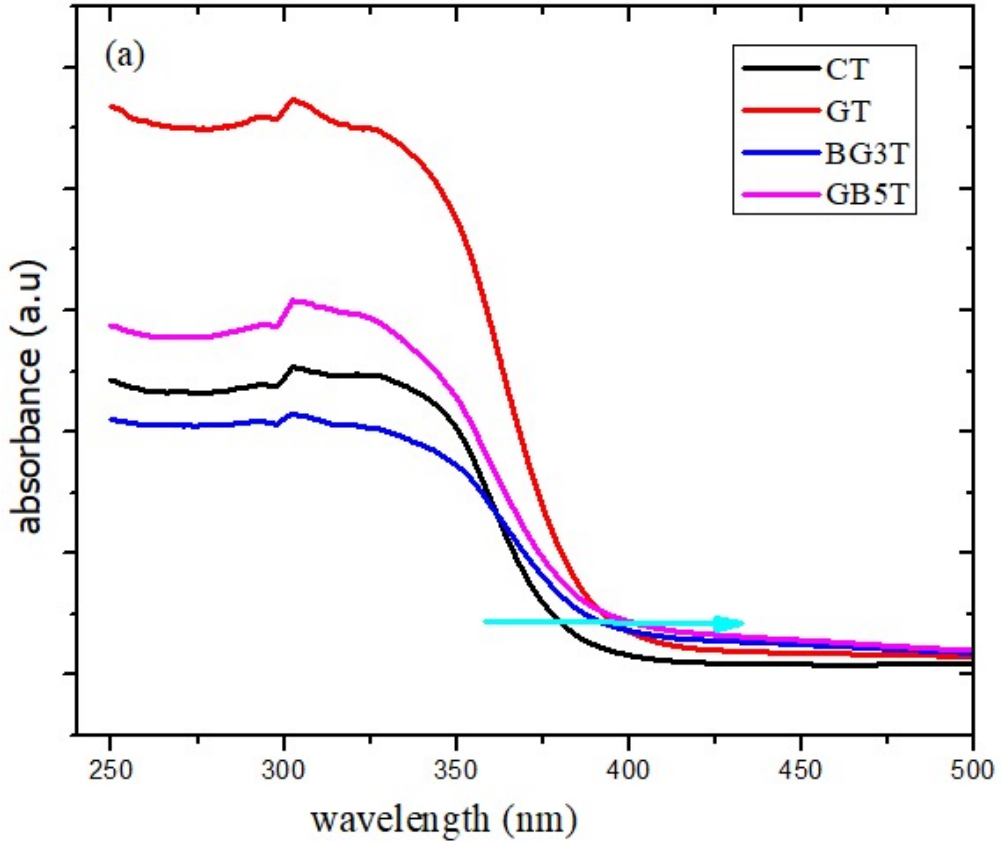


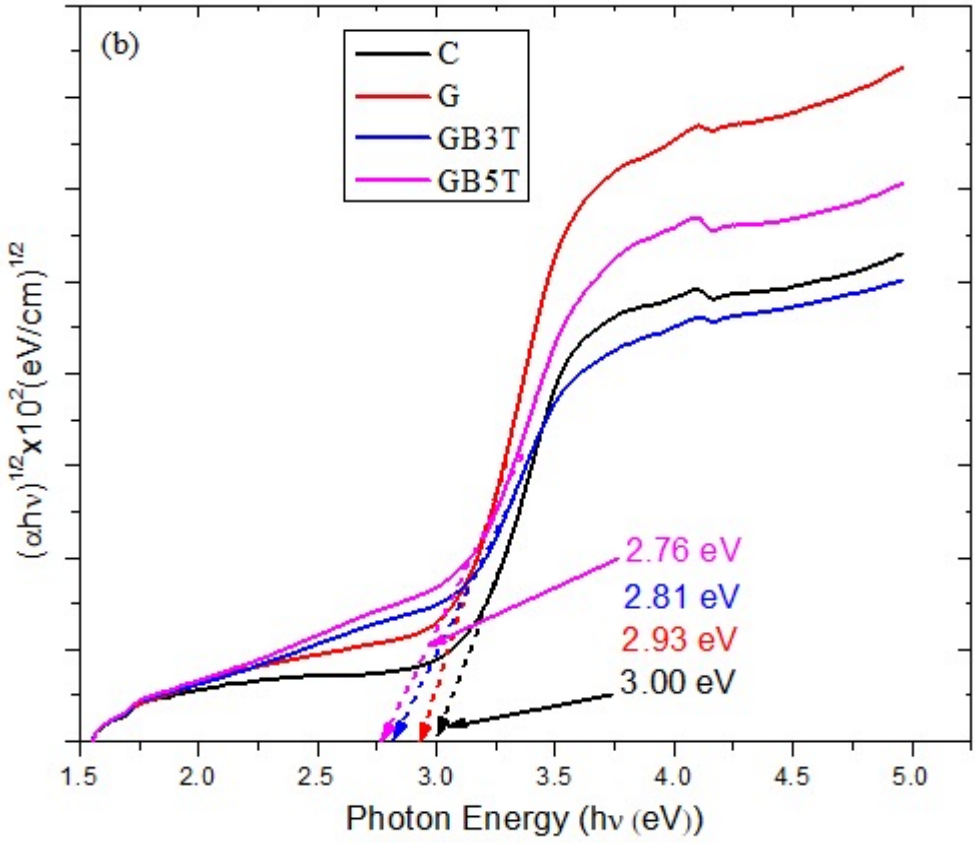
Crystallite Size



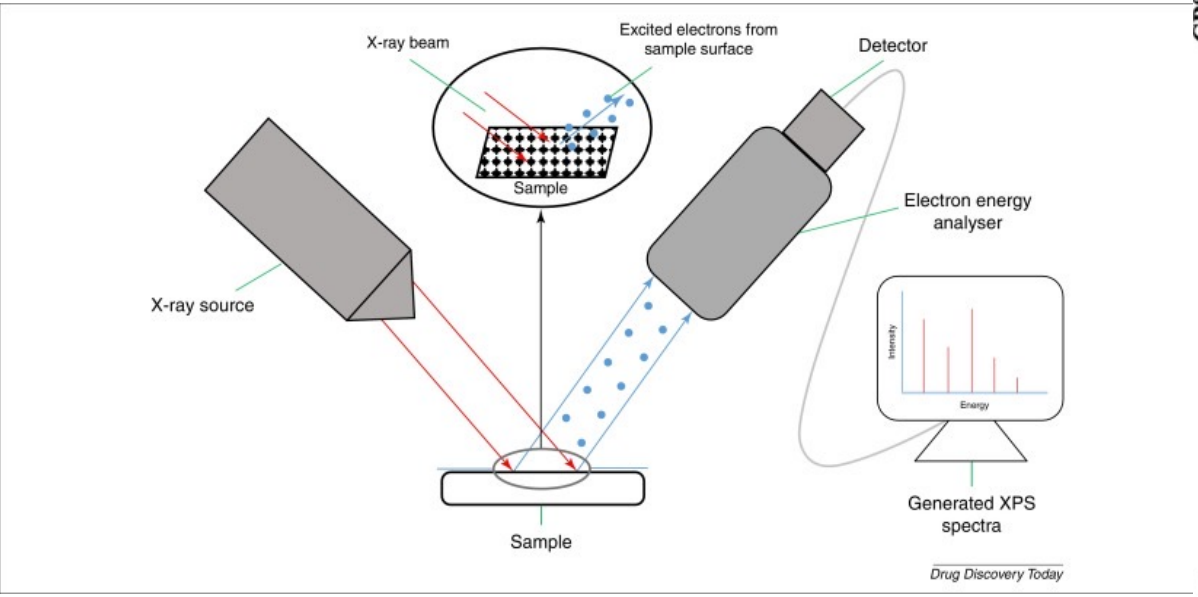
❖UV-Vis

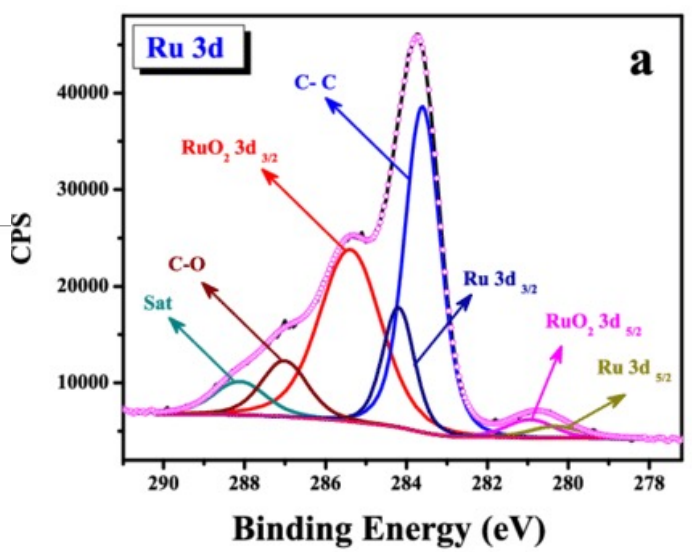
$$(\alpha h\nu)^n = A(h\nu - E_g)$$

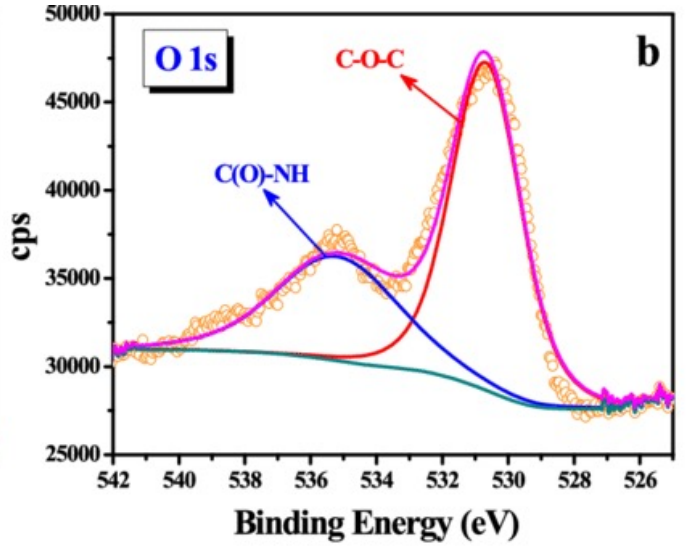


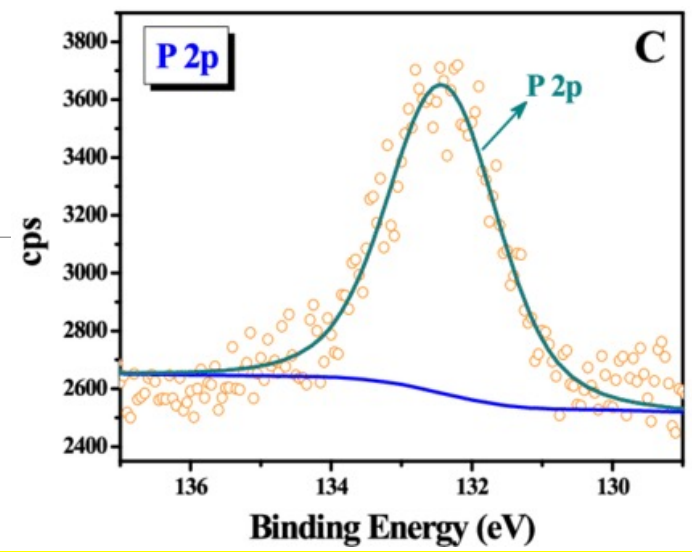


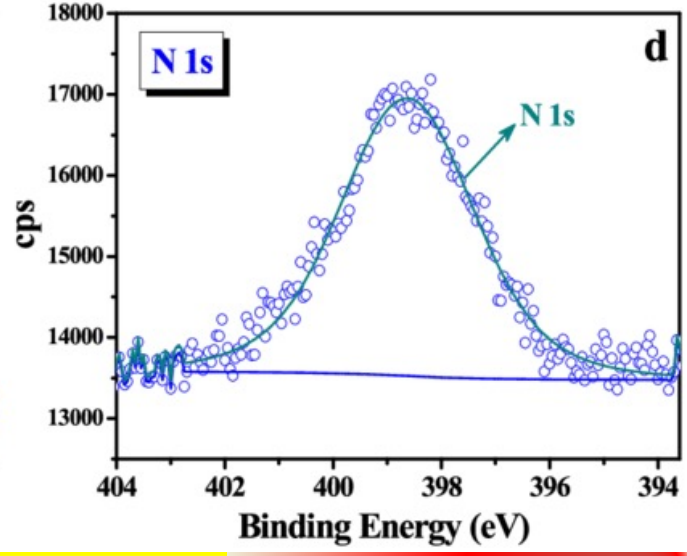
❖XPS


X-ray beam
Excited electrons from sample surface
Detector
Sample
Electron energy analyser
X-ray source
Generated XPS spectra
Sample
Drug Discovery Today


Ru 3d
a
C- C
RuO2 3d3/2
C-O
Sat
Ru 3d3/2
RuO2 3d5/2
Ru 3d5/2
CPS
Binding Energy (eV)


O 1s
b
C-O-C
C(O)-NH
cps
Binding Energy (eV)


P 2p
C
P 2p
cps
Binding Energy (eV)


N 1s
d
N 1s
cps
Binding Energy (eV)

2. Modification of Nanostructured Materials

☞Nanoparticles

limitations
(drawbacks)

- ❖ Hetero-sturcture
- ❖ Core-shell
- ❖ Doping
- ❖ Alloying

- ➢ Band gap energy
- ➢ Recombination rate of photo-induced charge
- ➢ Thermal/chemical stability
- ➢ Morphology/surface function

❑ Nanocomposite

- ➢ Enhanced
- ➢ Modified
- ➢ New/unique

properties

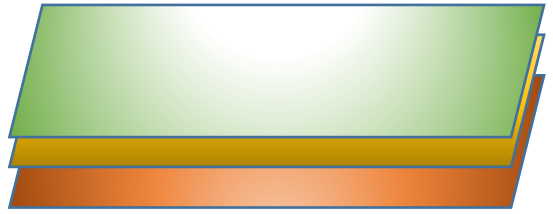
2. Modification of (Cont'd)

- Hetero-structure

➢ Any structure made from two or more than two different materials which have a hetero-junction.

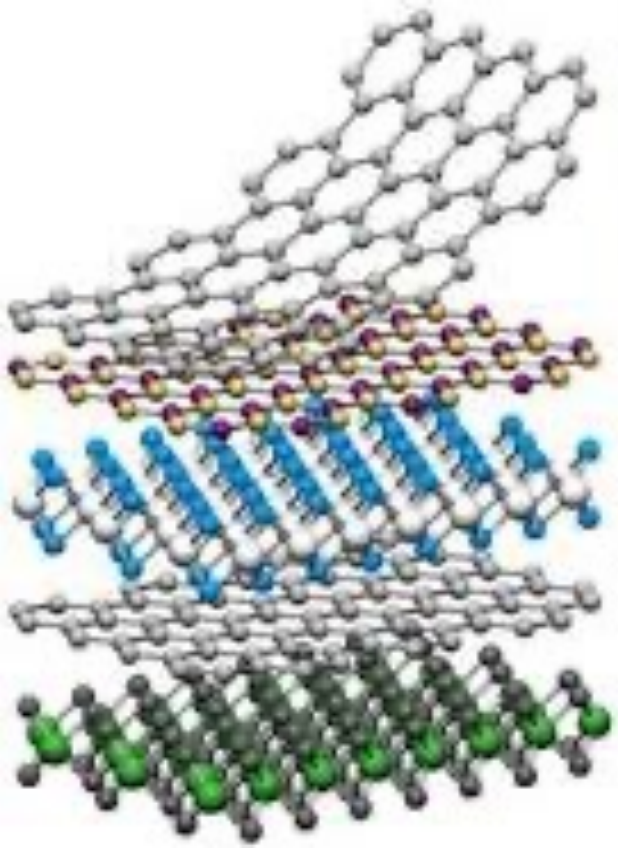
❖ Hetero + structure

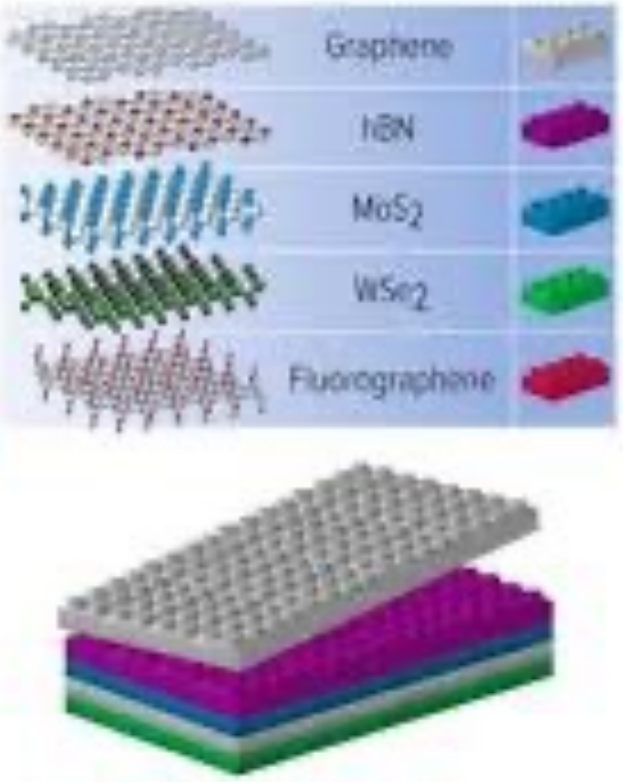
- A hetero-unction is an interface between two layers or regions of dissimilar materials. These materials have unequal band gaps as opposed to a homo-junction. It is often advantageous to engineer the electronic energy bands in many applications.

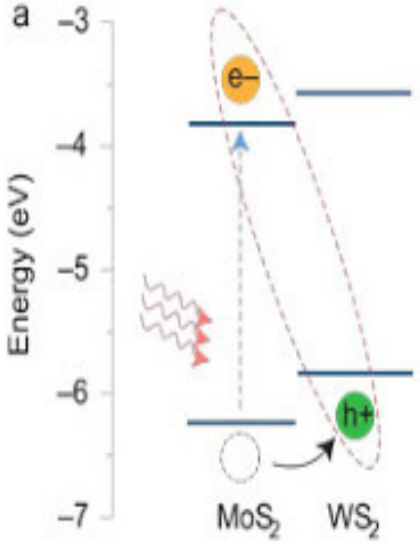


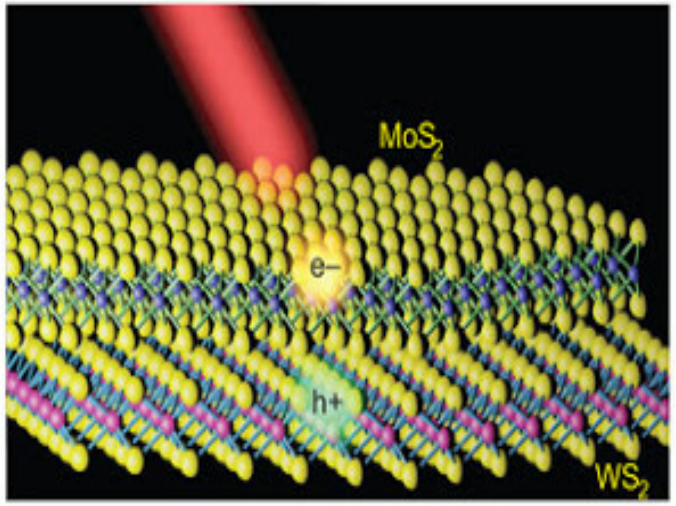
2. Modification of (Cont'd)

☞ Hetero-structure





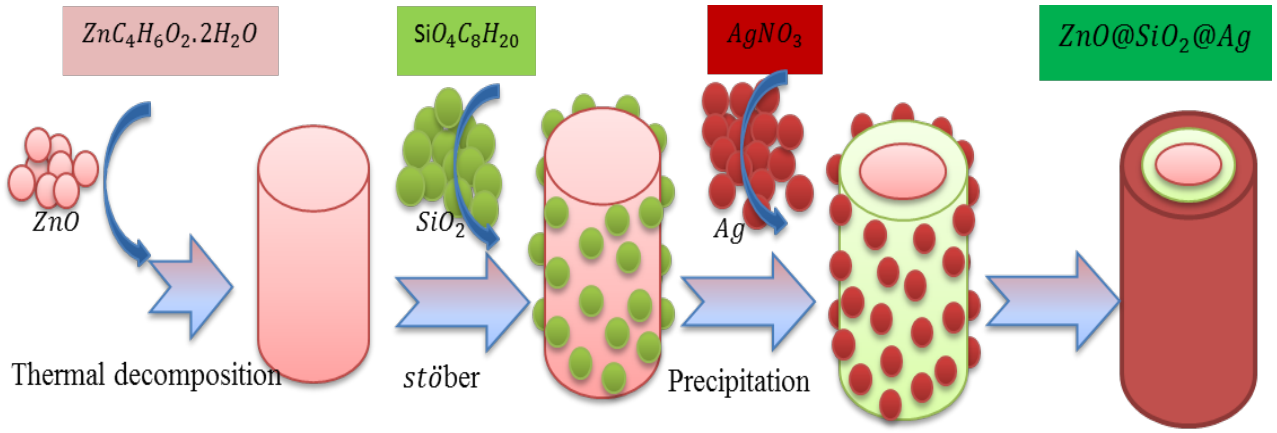




2. Modification of (Cont'd)

❖ Core-shell

- A special kind of hetero-structure
- A class of materials which have properties intermediate between those of constituents



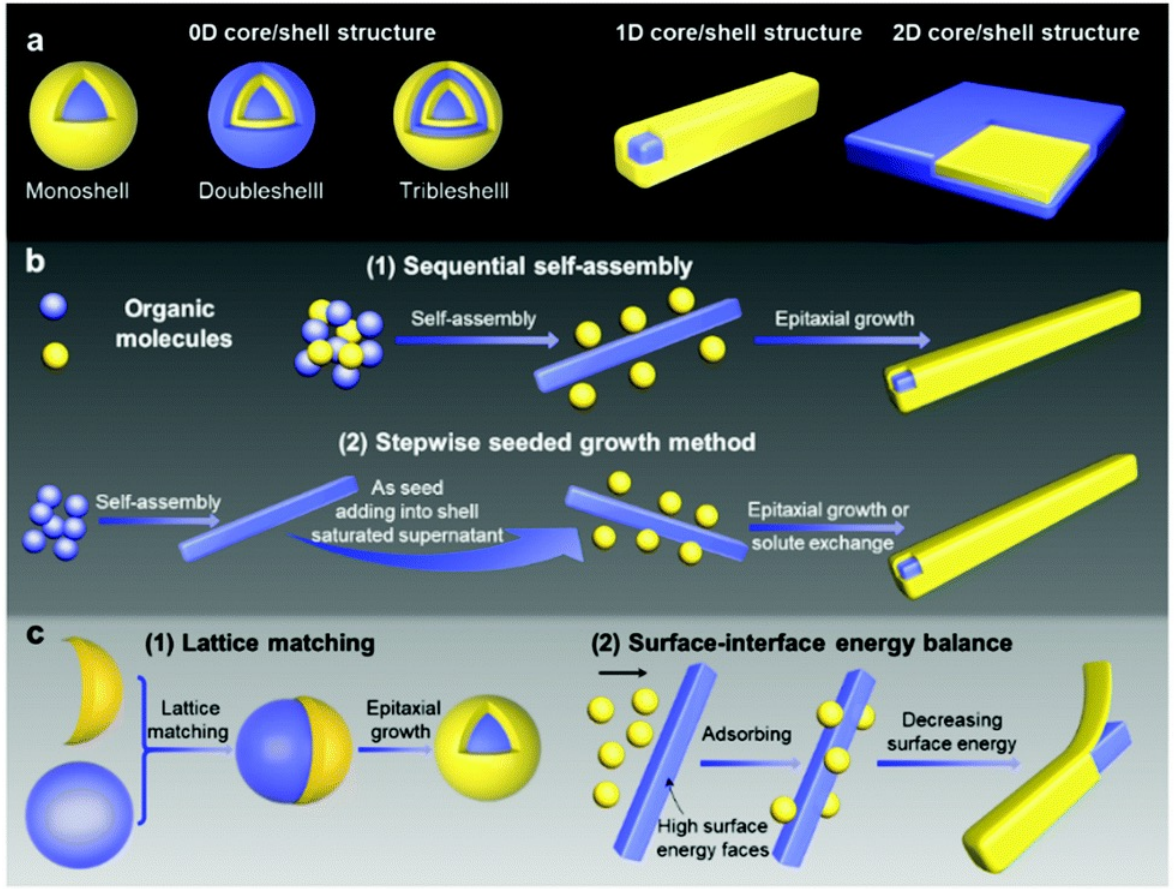
❖ Core shape/size
❖ Shell thickness/shape
❖ Number of layer
❖ Material type
❖ Surrounding medium
❖ Composite shape/size

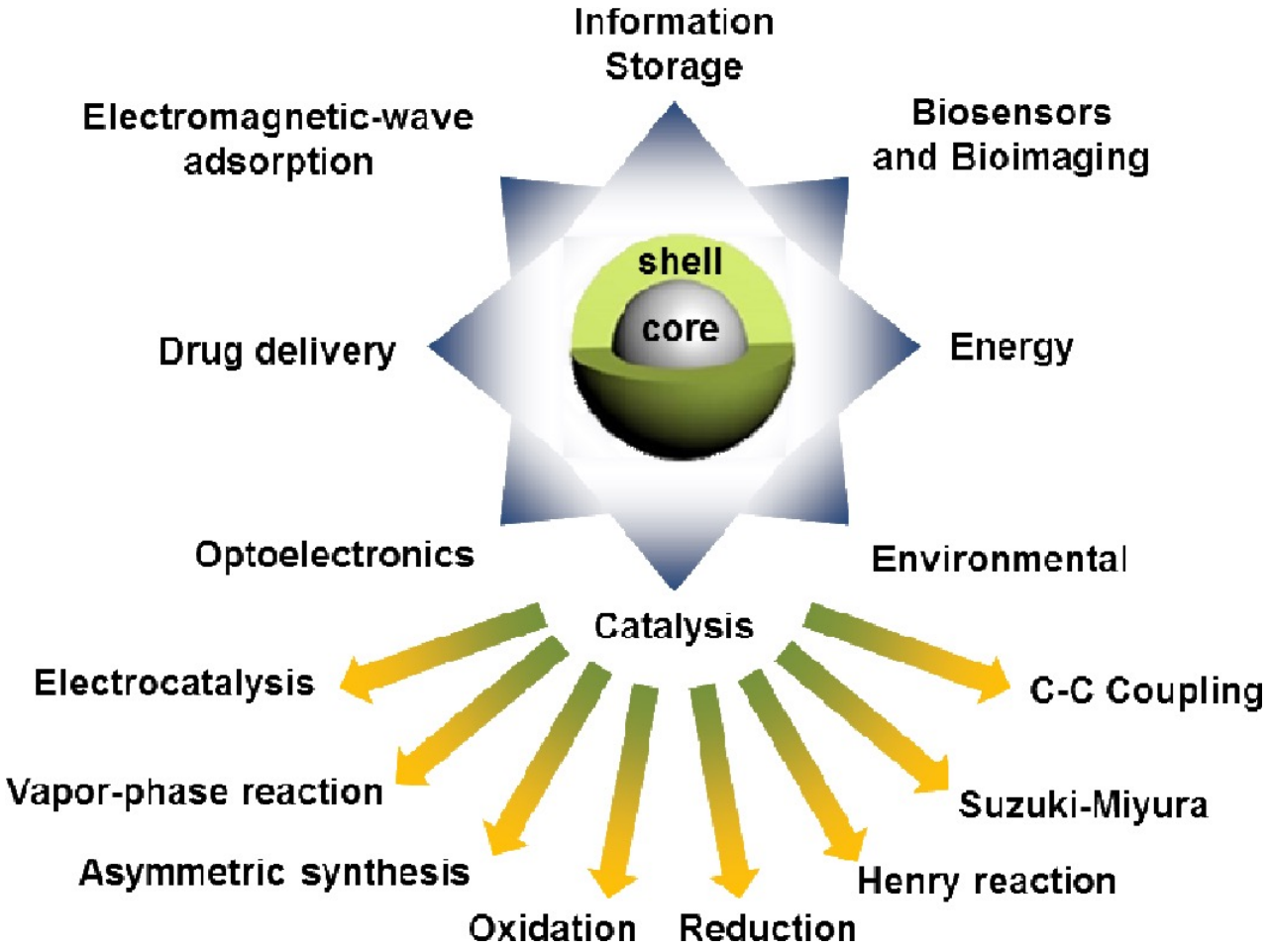
❖ Shell usually used as the barrier between the core material and the surrounding material

- Alter a charge
- Surface reactivity
- Functionality
- Stability
- Toxicity
- Dispersive ability
- Cost-effectiveness

2. Modification of (Cont'd)

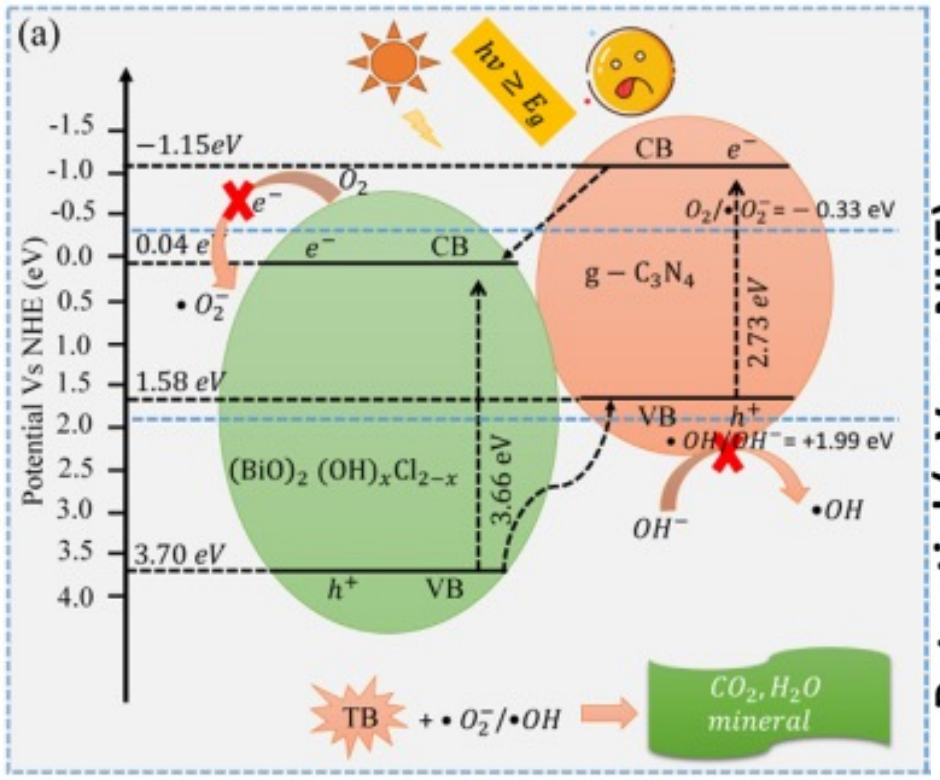
☞Core-shell

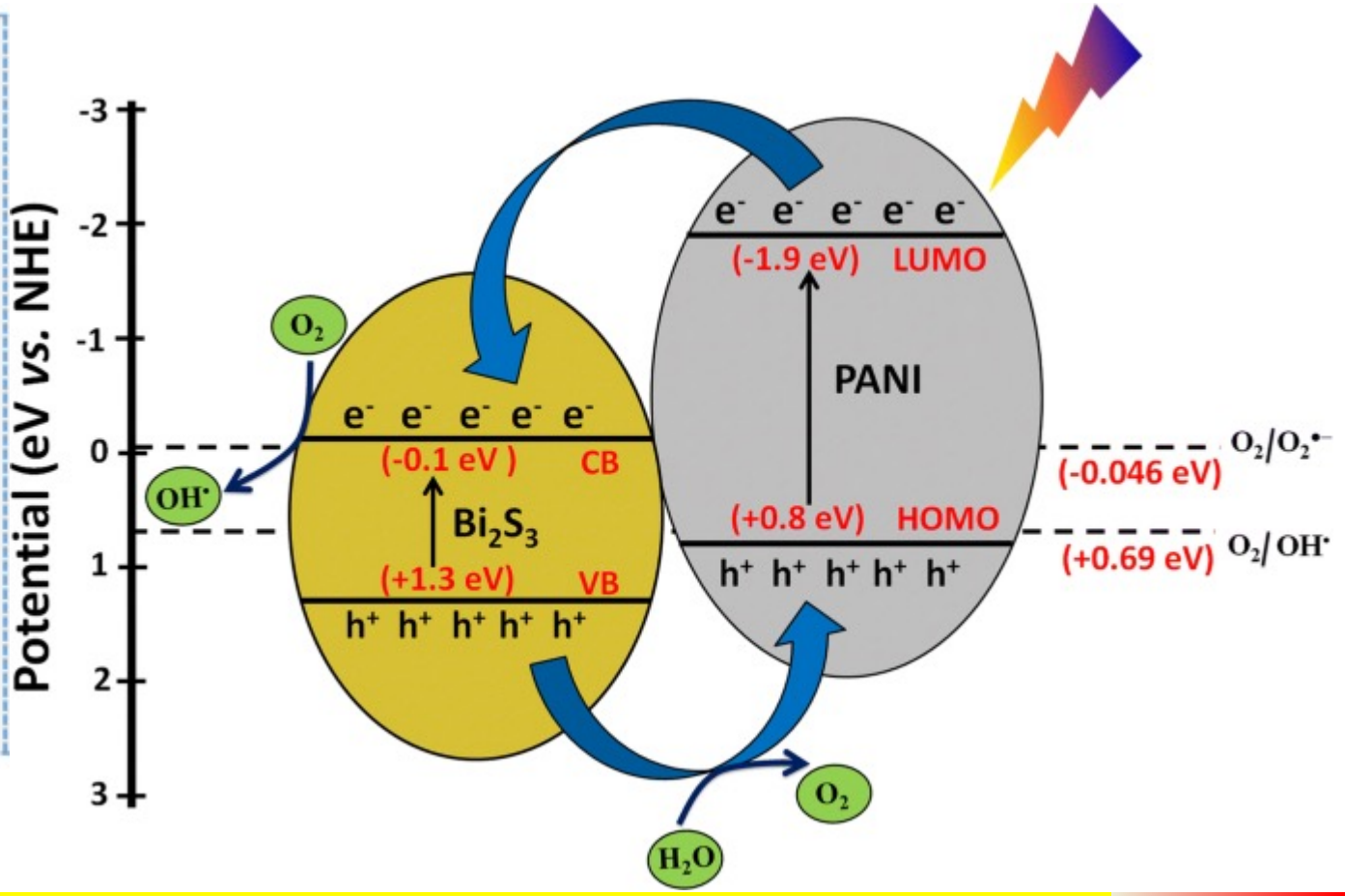




2. Modification of (Cont'd)

- Band gap energy modify by synthesize thecnique and combine with other materials.
- The recombination photo induced charge is mostly modified by combining with other novel material.





❑ Nanocomposite

❖ Nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100nm or structures having nano-scale repeat distances between the different phases that make up the material.

- Photo-catalysis
- Solar-cell
- Biological application
- Pharmaceutical application
- Drug delivery
- Electronics device
- Energy/data storage
- Cosmetics

➢ Photo-catalysis is defined as "acceleration of a photo-generated electron in the presence of a catalyst," in which the catalyst neither undergoes any changes nor is consumed in the reaction.

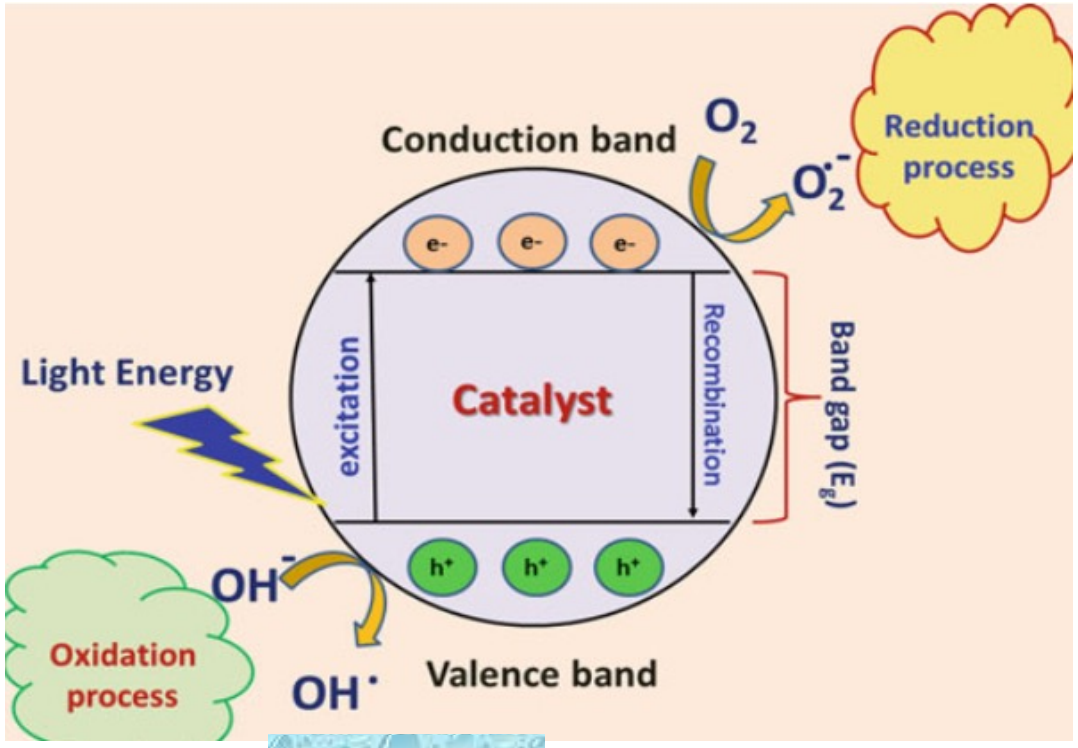
Photo-catalysis is generally defined as the catalysis of a photochemical reaction at a solid surface.

❖Photo - catalysis

- ✓ Photon
- ✓ Catalyst surface
- ✓ Oxidizing agent

- Flexibility of treatment
- Efficiency
- Recyclability
- Eco-friendliness/ Cost-effectiveness

- ✓ Size/structure/morphology
- ✓ Surface area/ temperature/light intensity
- ✓ Concentration of catalyst/waste water



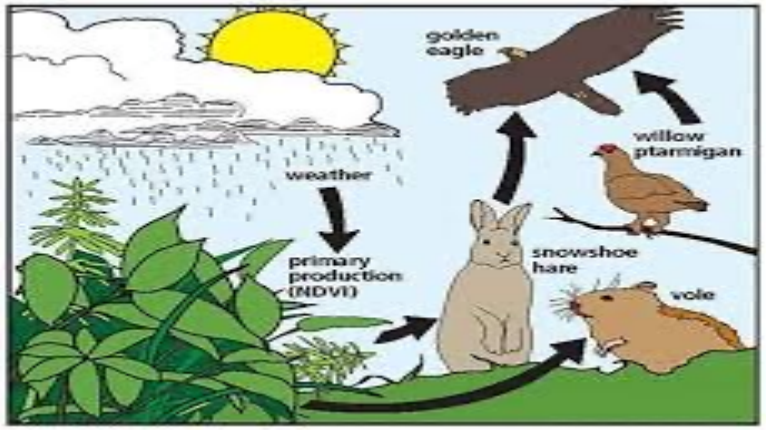
Catalysis

- ➢ Non-toxic
- ➢ Cost-effective
- ➢ Relative abundance
- ➢ Easy to fabricate
- ➢ Show different properties

3. Analysis the Efficiency (Cont'd)

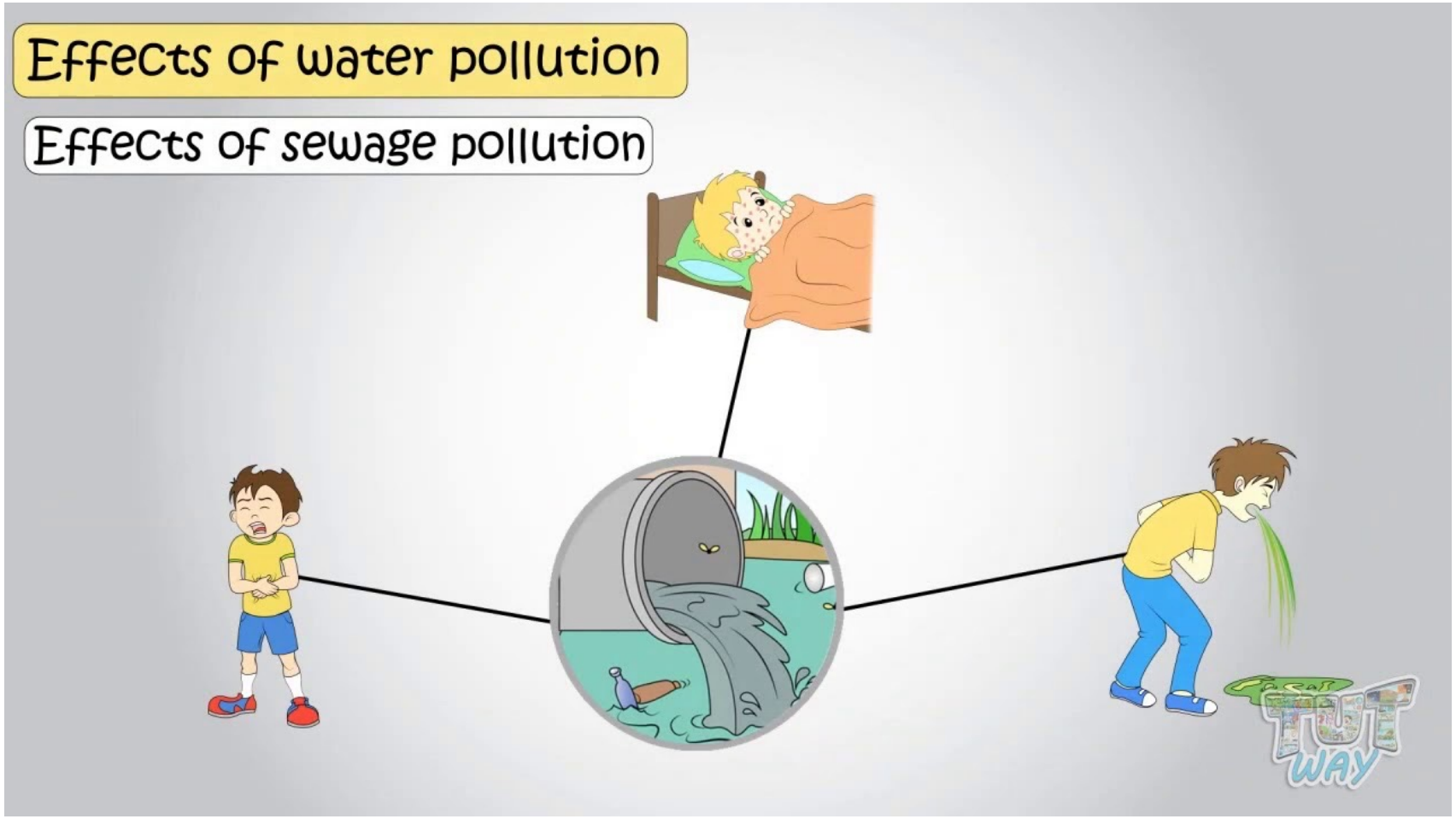
❖ *Photo-catalysis* is an active method that uses the sun energy to degrade many different pollutants which are exist in the water.

❖ Water can be use for different purposes: for instance for our life and keep ecosystem.



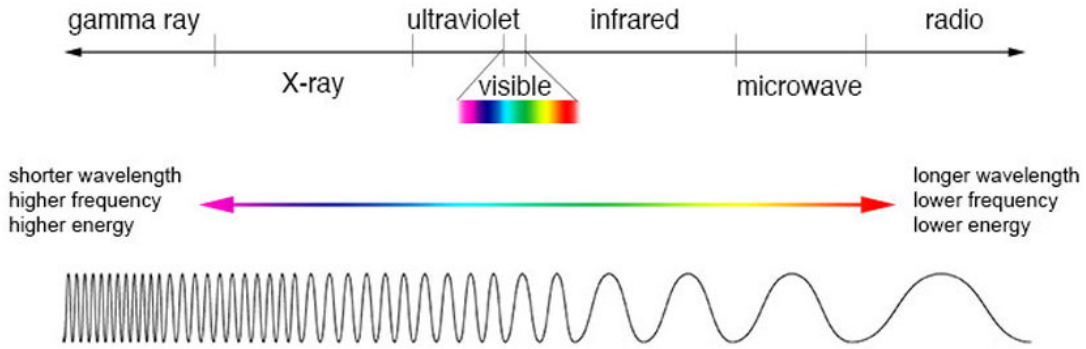
3. Analysis the Efficiency (Cont'd)

❖ Water body mostly polluted by waste material of industries/factories.



3. Analysis the Efficiency (Cont'd)

- For photo-catalytic application, we have to use solar radiation.
- Visible light have proper photon energy to degrade polluted water.



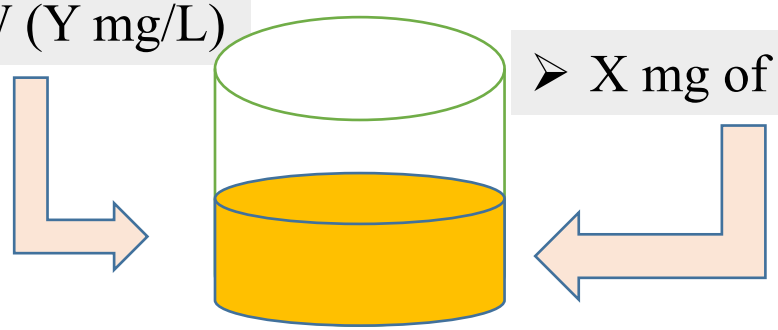
WAVELENGTH AND ENERGY OF THE VISIBLE SPECTRUM COLORS

COLOR	WAVELENGTH	ENERGY
Red	700 nm	1.771 eV
Reddish orange	650 nm	1.909 eV
Orange	600 nm	2.067 eV
Yellow	580 nm	2.138 eV
Yellowish green	550 nm	2.254 eV
Green	500 nm	2.480 eV
Blue	450 nm	2.765 eV
Violet	400 nm	3.100 eV

3. Analysis the Efficiency (Cont'd)

Photo-catalytic Degradation of Polluted Water (PW)

- 100 mL of PW (Y mg/L)
- X mg of Sample



- Ultra-sonicated for ~30 min
- dark place
- Radiated by visible light
- withdrawn within required time interval

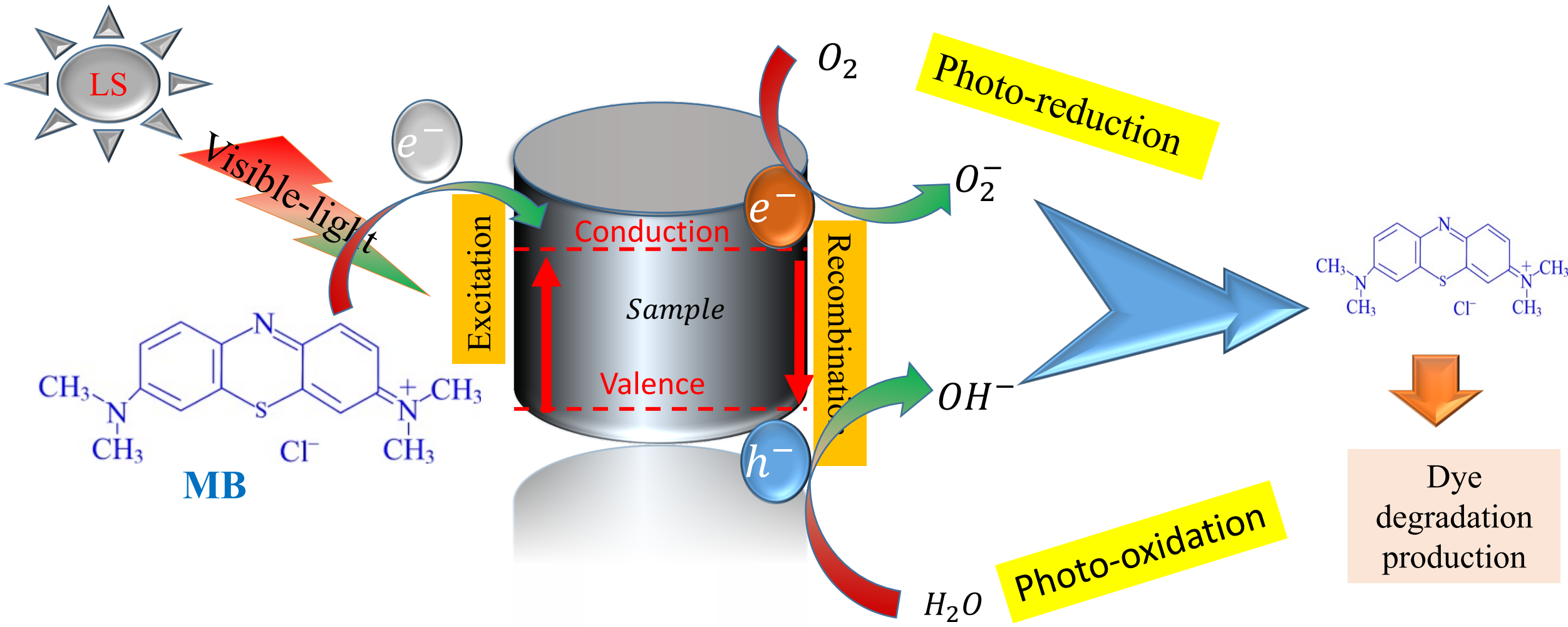
- Proper homogeneity
- Absorption-desorption equilibrium

✓ Centrifuge with 1200 rpm for 5 min

✓ 200-800 nm using pure water

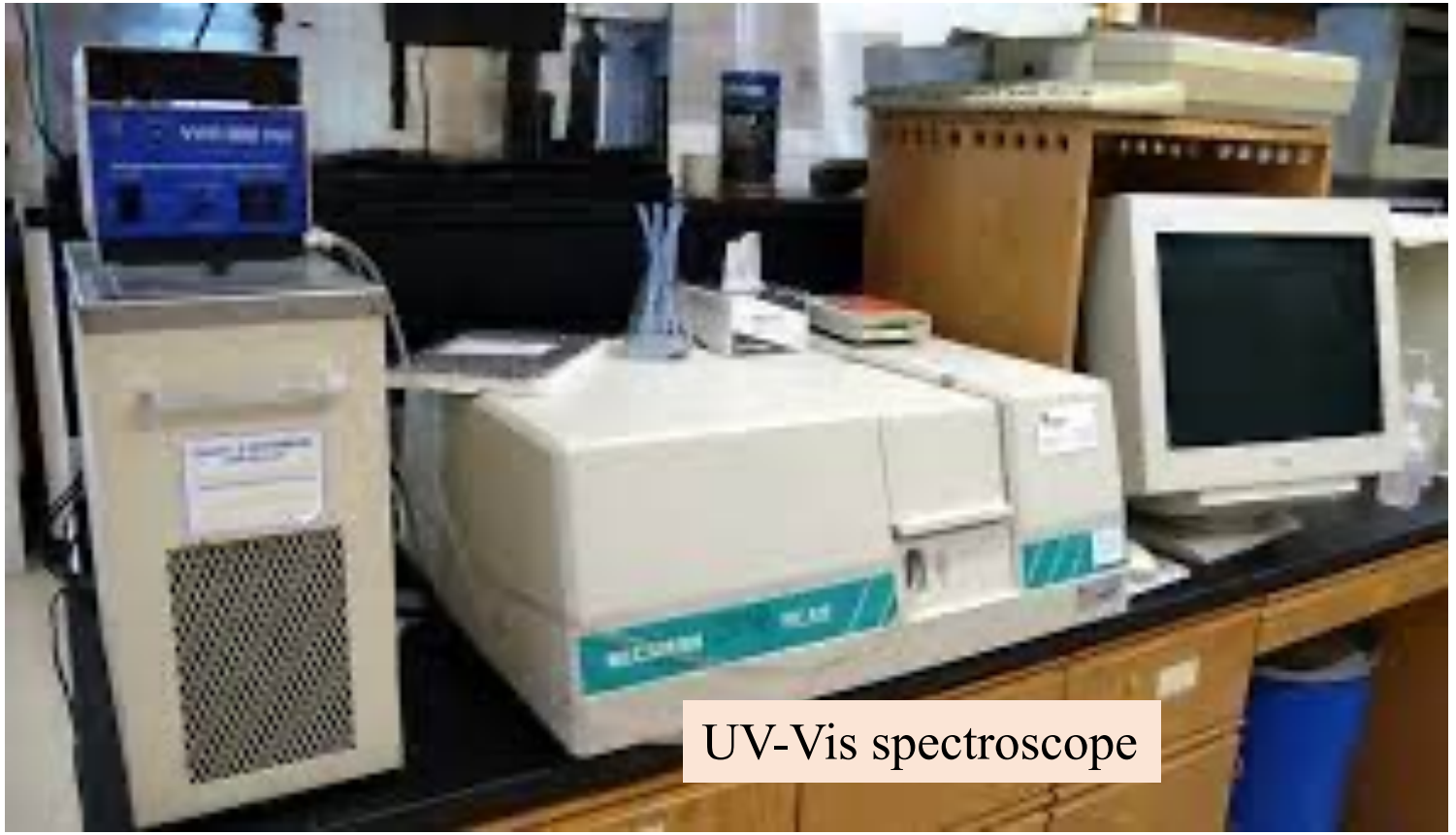
✓ UV-Vis spectroscopy

3. Analysis the Efficiency (Cont'd)



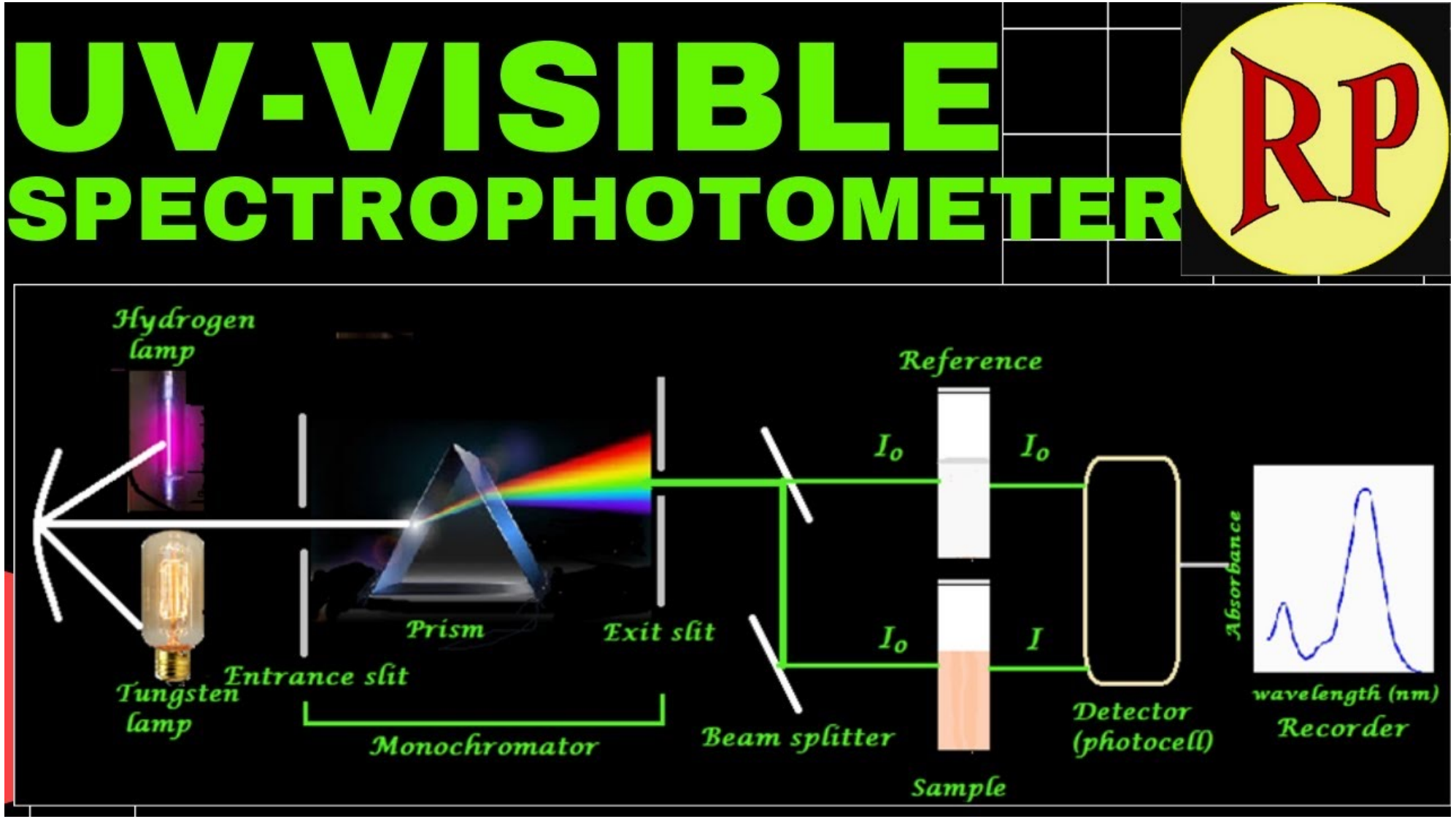
3. Analysis the Efficiency (Cont'd)

Photo-reactor



UV-Vis spectroscope

Centrifuge


UV-VISIBLE
SPECTROPHOTOMETER
RP
Hydrogen lamp
Tungsten lamp
Entrance slit
Prism
Exit slit
Monochromator
Reference
I_o
I_o
I_o
I
Beam splitter
Sample
Detector (photocell)
Absorbance
wavelength (nm)
Recorder

3. Analysis the Efficiency (Cont'd)

❖ Beer-Lambert law

$$I = I_0 e^{-(c \times l)}$$

$$Absorbance\ (A) = \varepsilon \times c \times l$$

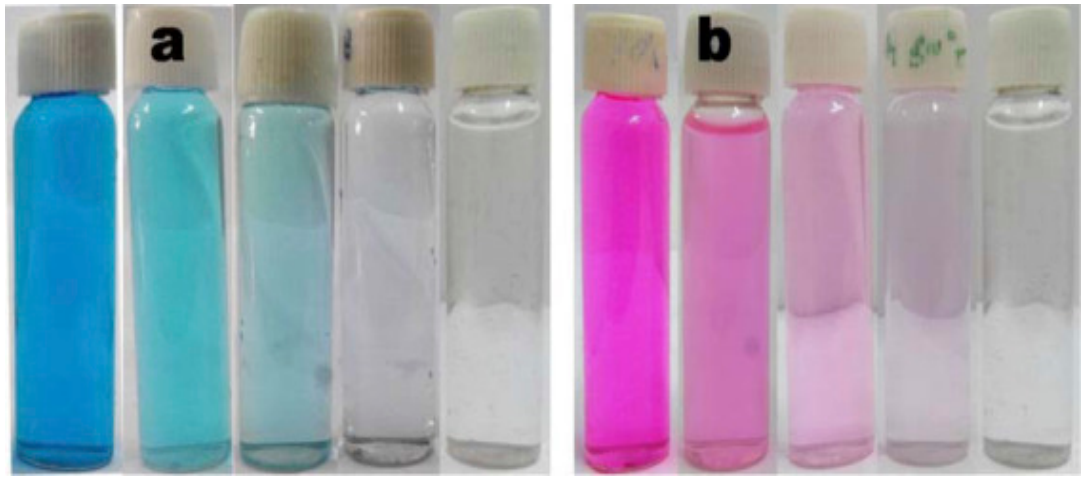
Concentration C of pollutant in the solution

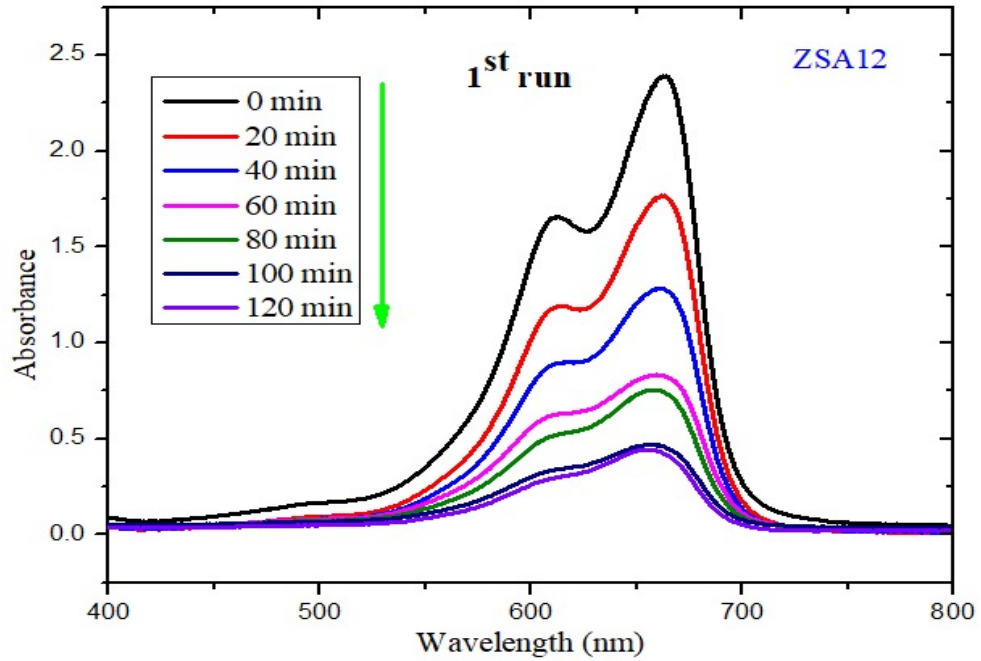
$$c = \frac{A}{\varepsilon \times l}$$

✓ ι is width of cuvette

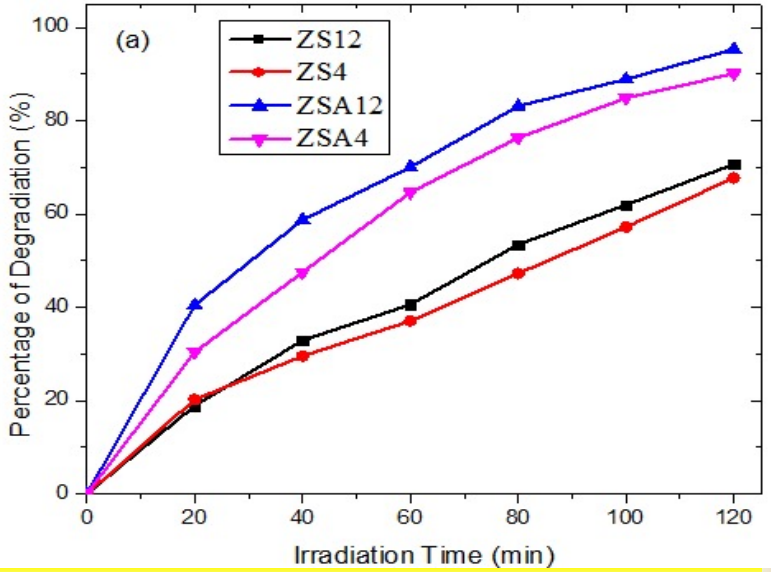
ε is molar extinction coefficient

3. Analysis the Efficiency (Cont'd)

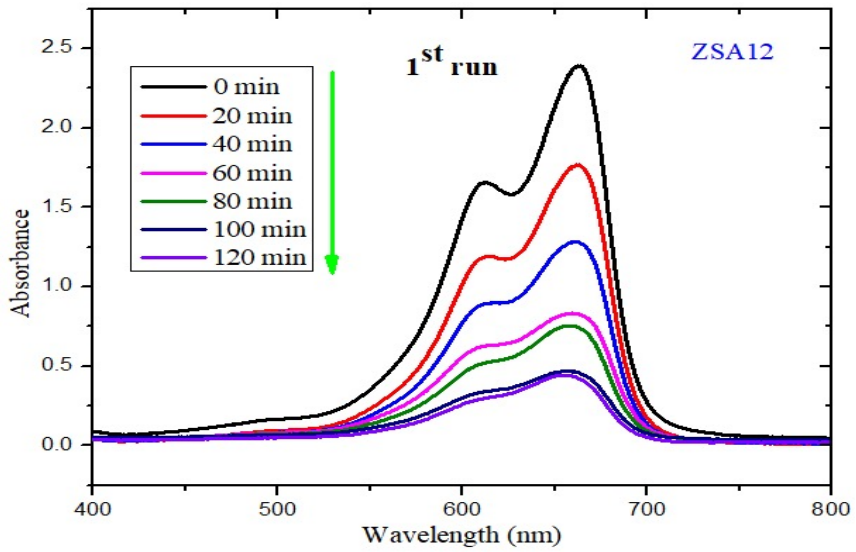


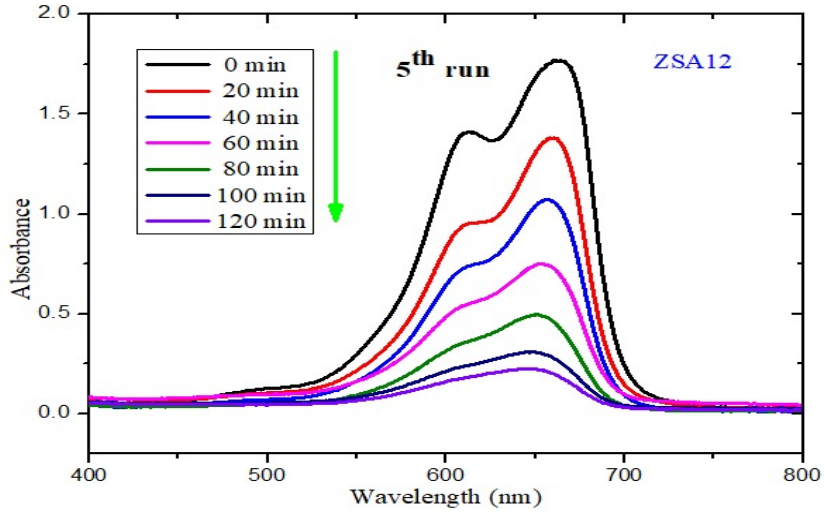


➲ $\mathrm{DP} = \frac{C_0 - C_t}{C_0} \times 100\ (\%)$

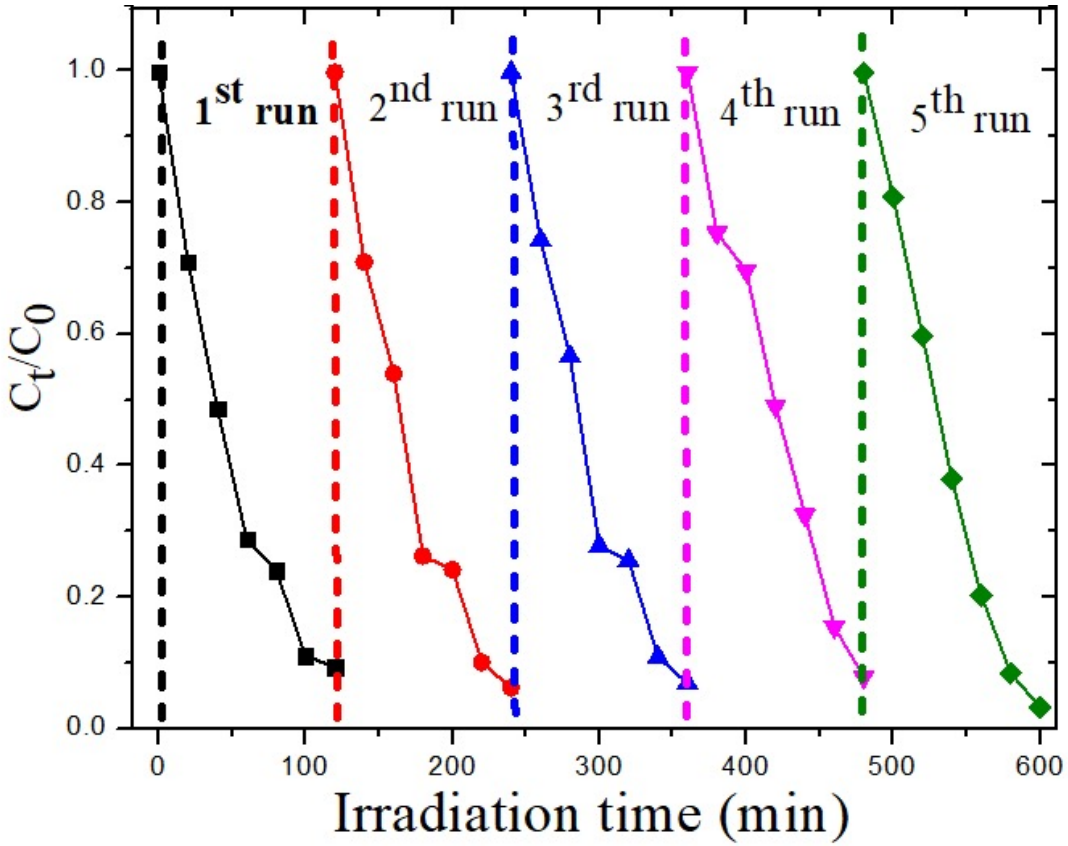


3. Analysis the Efficiency (Cont'd)





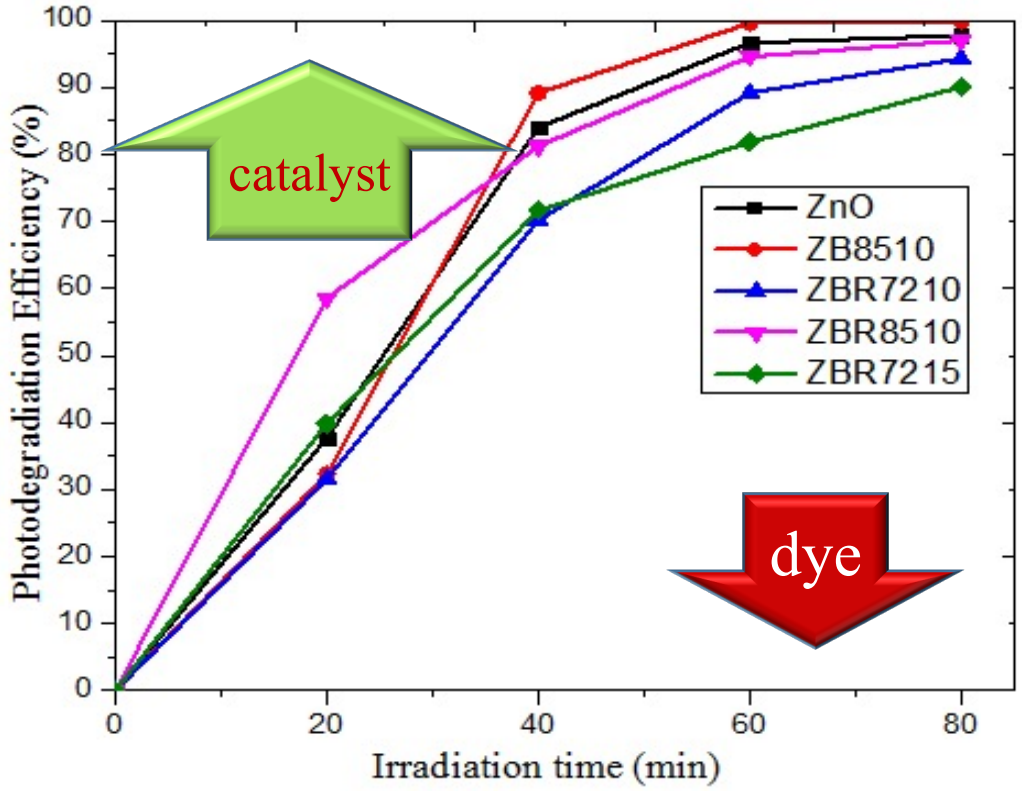
- Recyclability of materials

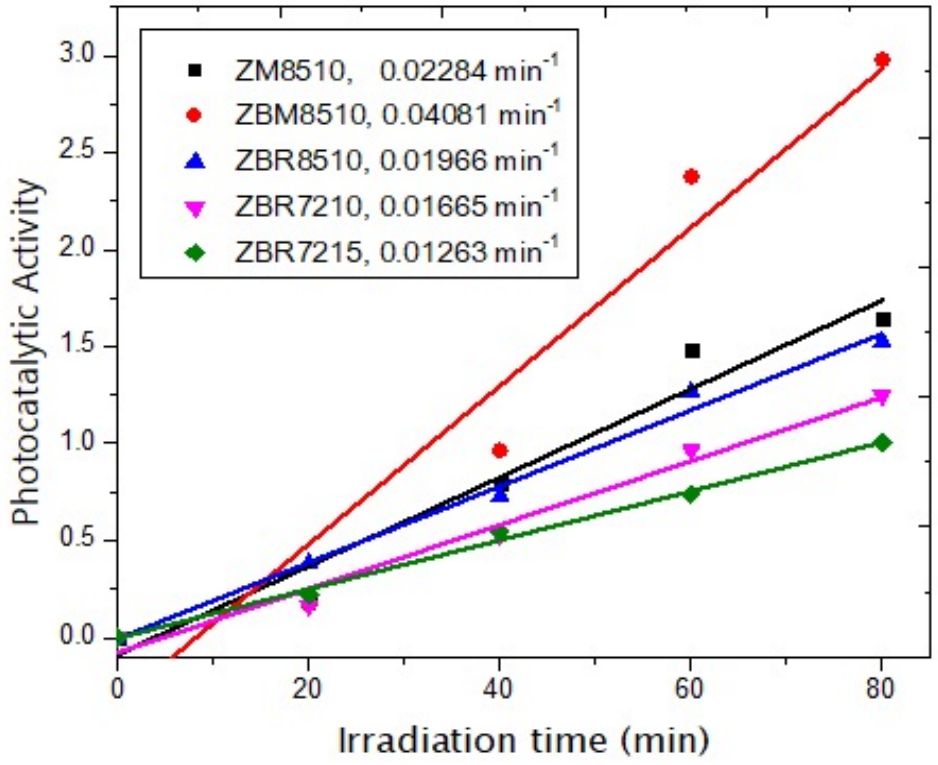


3. Analysis the Efficiency (Cont'd)

➢the degradation of polluted water depend on the concentration dye (polluted water) and catalyst (our sample).

$$kt = \ln(C_0/C_t)$$





4. Target

Drawback → Modifying

4. Conclusion

- Nanostructured material
- Drawbacks of nanoparticles
- Modification the drawback of nanoparticles
- Fabrication and characterization techniques of nanostructured materials
- How to analyze the photocatalytic efficiency of nanostructured material

Thank you