Metal-TiO_2 Nano-Photocatalysts for Detoxification of Toxic Pesticides, Dyes, Polyaromatics Pollutants and Bacteria under UV-Sunlight Irradiation

Pollution Control 2016

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Pollution Control & Sustainable Environment

April 25-26, 2016 Dubai, UAE

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Professor and Head

School of Chemistry and Biochemistry

Thapar University, Patiala-147004

Punjab

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www.thapar.edu

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Established	: 1956
Deemed University	: 1985
Lush Green Campus	: 251 Acre
Departments	: 07
Schools	: 06
Centres	: 05
UGC-NAAC	: A grade
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Placement Highlights 2015-16

- 94% Students Placed
- 175+ Number of Recruiters
- 23 Lacs (P.A.) Highest Salary
- 6 Lacs (P.A.) Average Salary

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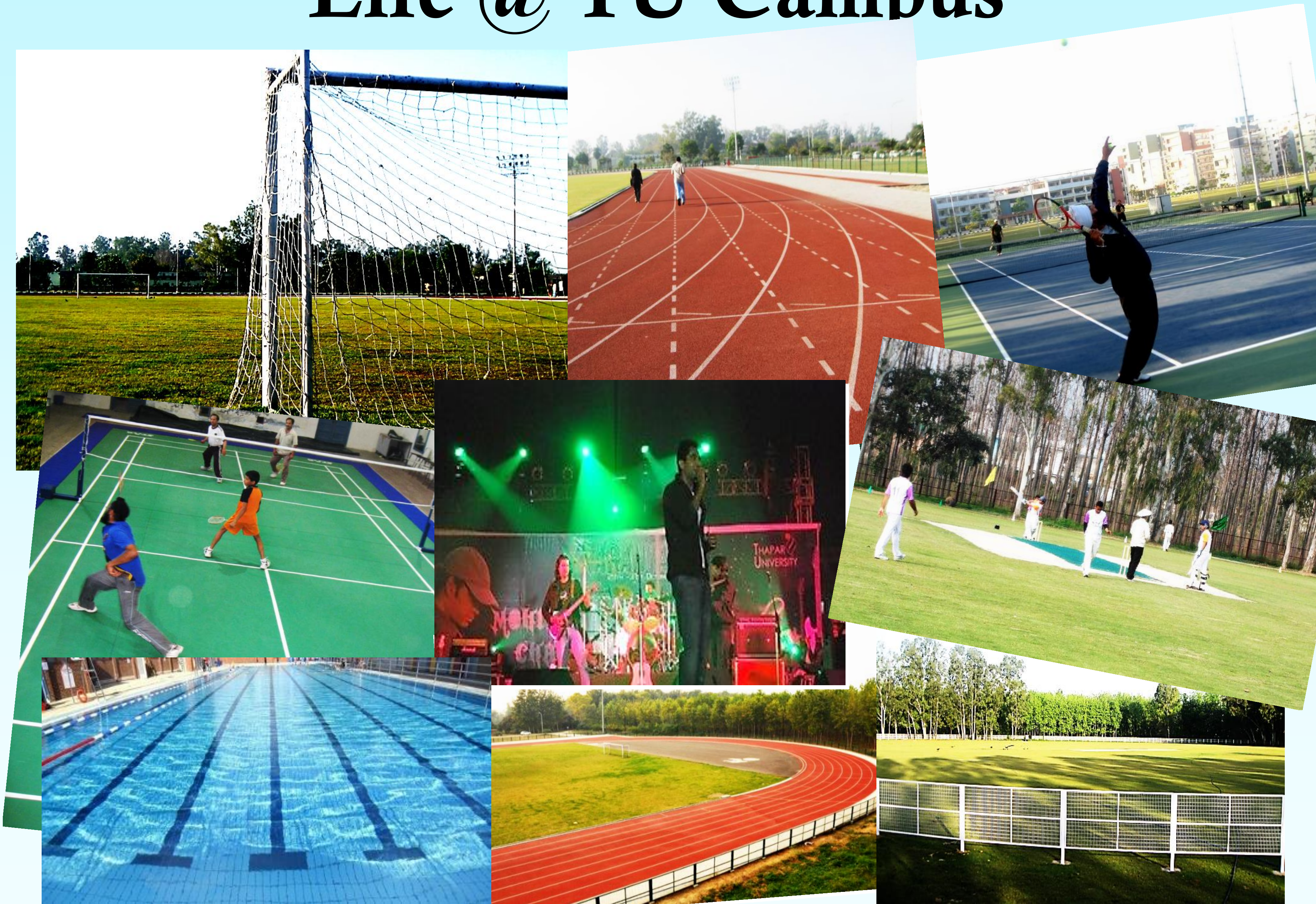
- No. 1 in placement in the region (90-100%)
- NO RAGGING INSTITUTE
- Fully residential campus; 7000 students;
  6 Boys hostels + 4 Girls hostels

Life @ TU Campus






Life @ TU Campus

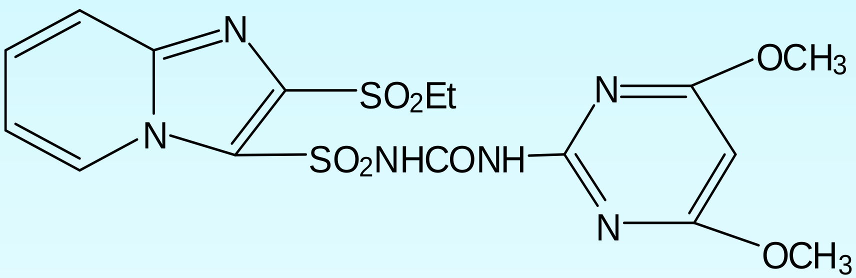
Photocatalytic Degradation of Toxic Pesticides, PAHs, Dyes and Photokilling of pathogenic/agro bacteria using greener processes

Classification

Pesticides
- Herbicides (Sulfosulfuron)
- Insecticides (Imidacloprid; Methyl Parthion)
- Biocides (Carbamate)
- Fungicides (Blasticidin S; Biphenyl)

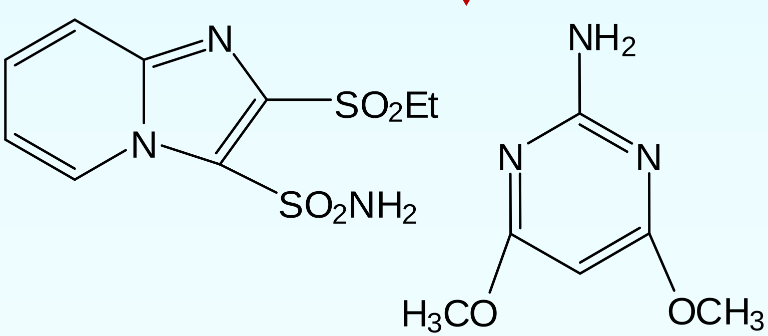
Natural degradation: using sunlight or biodegradation

Disadvantage: Slow and intermediates (Toxic/ Non-toxic)



Sulfosulfuron ($t_{1/2}$ ~162 days)

Photolysis



Highly toxic than parent.

➢ ***Persistent in nature***

Only 0.1% of amount reached to the target species.

Adverse effects

Reproductive disorder, Premature babies,

Highly contaminated area Malwa region of Punjab having **cancer** cases: 560/100000 population

Polycyclic Aromatic Hydrocarbons (PAHs)

- ❖ Produced due to incomplete combustion[1] of organic mass.
- ❖ Huge amount of straw stubble burning in Punjab

❖ *Present in :*

•Cooking oil
(0.15- 13.98μg/kg)

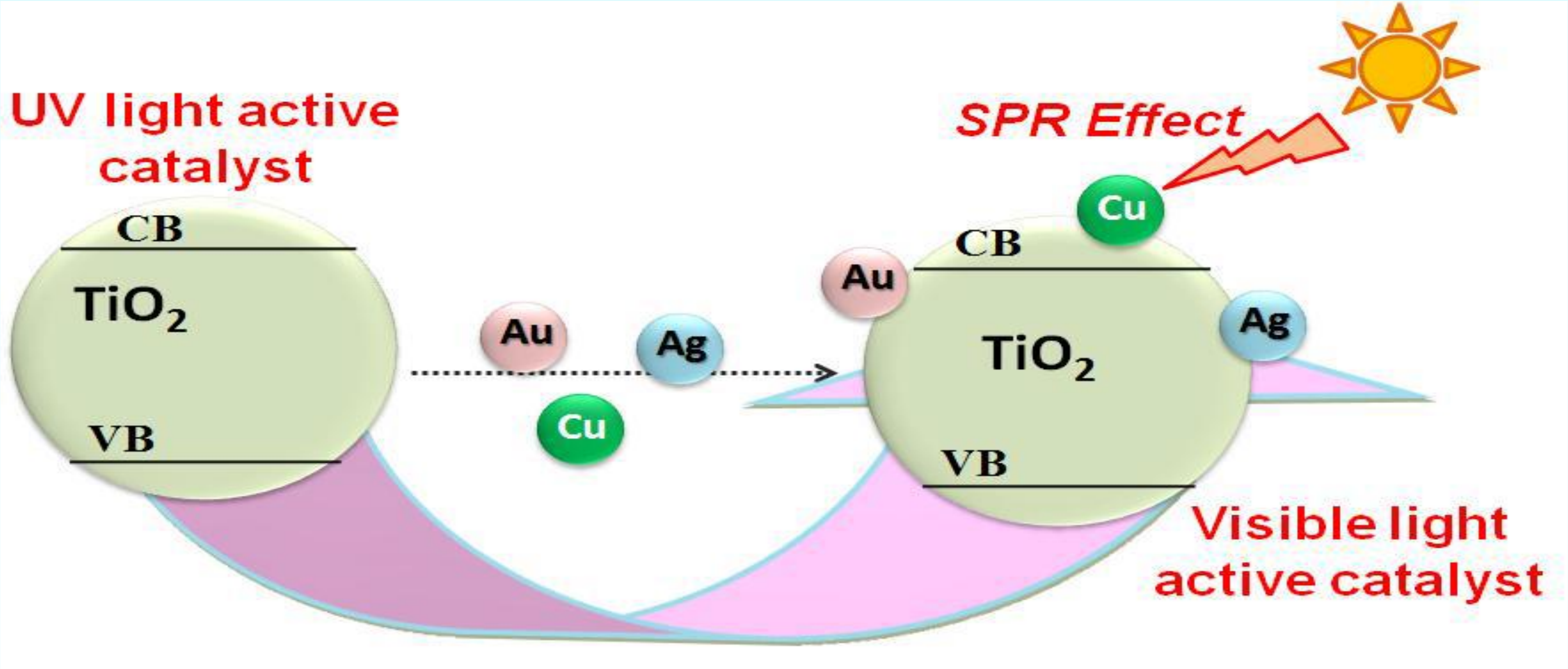
•Air
(0.41-8.2ng/m^3)

•Soil
(0.79-15.9 ng/kg,
burning of crop waste)

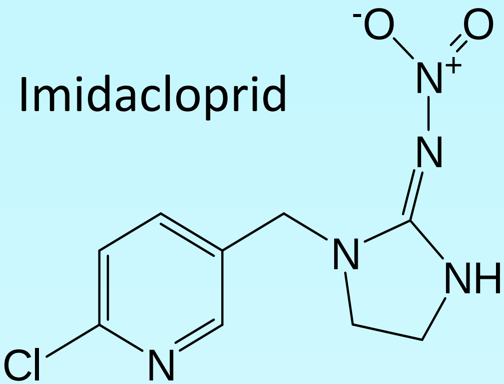
S. No.	Name	Classification	
		(US EPA, 1997)	(IARC)
1.	Naphthalene	√	2B
2.	Phenanthrene	√	--
3.	Anthracene	√	--
4.	Acenaphthylene	√	--
5.	Dibenz[a,h]anthracene	√	2A
6.	Benz[a]anthracene	√	2A
7.	Benzo[b]fluoranthene	√	2B
8.	Acenaphthene	√	--
9.	Chrysene	√	--
10.	Benz[a]pyrene	√	2A
11.	Fluoranthene	√	--
12.	Indeno[1,2,3]pyrene	√	2B
13.	Fluorene	√	--
14.	Pyrene	√	--
15.	Benzo[k]fluoranthene	√	2B
16.	Benzo[ghi]perylene	√	--

2A: Probabal human carcinogenic; 2B: Possible human carcinogenic

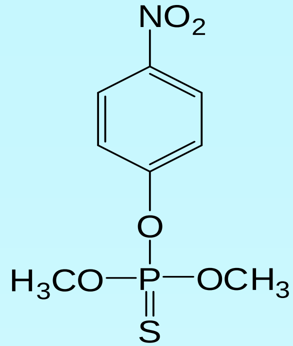
- Influence of heteroatoms (N, Cl, O, P, S etc.,) present in pesticides, for imparting the stability, toxicity to the photoproduced intermediates need to be studied.
- Photodegradation of pesticides results in fragmentation of parent molecule into smaller intermediates that finally decomposes to CO_2 and inorganic ions. However, mechanism during degradation and the fate of heteroatoms present in the pesticides requires investigation..
- **Visible light sensitive TiO_2 photocatalysts of different shapes and sizes and effect of metal co-catalysts loading for effective mineralization of dyes, pesticides, toxic pyrene and killing of bacteria etc present in industrial effluents and agricultural land under UV/sun light exposure**



Imidacloprid



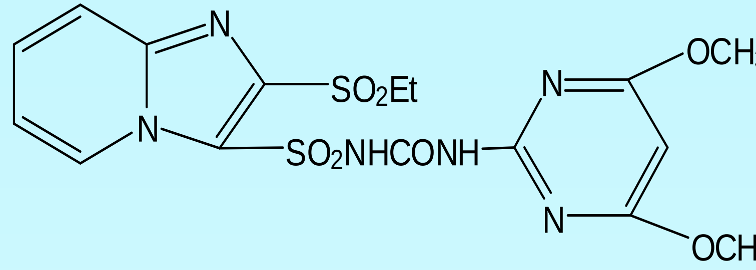
Extensively used,
Neurotoxic &
carcinogenic
$t_{1/2}$ = 30-162 days,
Solubility = 550 mg/l,
Causes: weakning of
breathing muscles



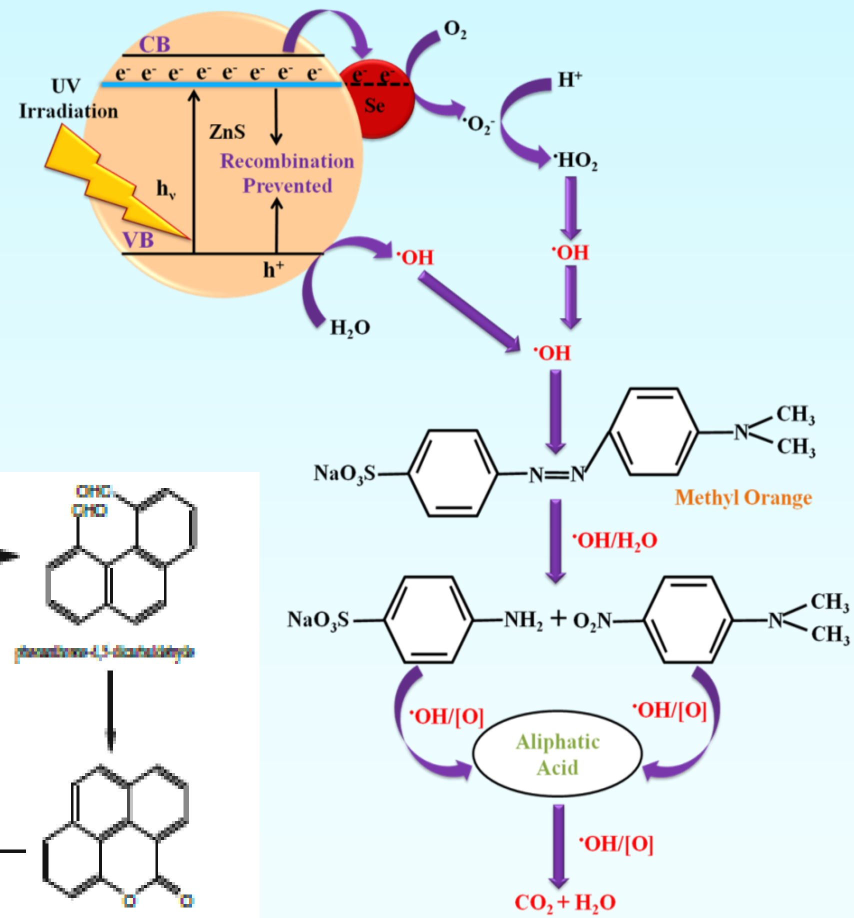
Methyl Parathion

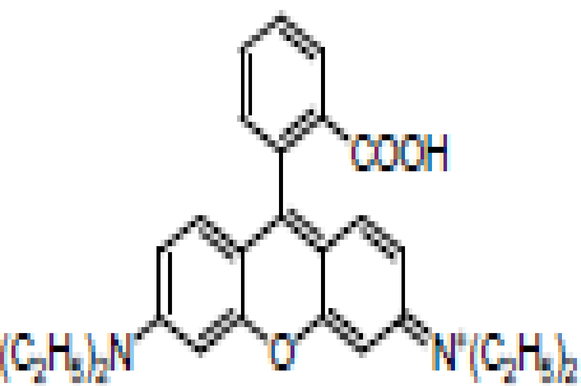
$T_{1/2}$ = ~179 days

❖**Potential Health Affects :**
Headache, loss of vision and conscious, severe depressions, sleep walking, and death

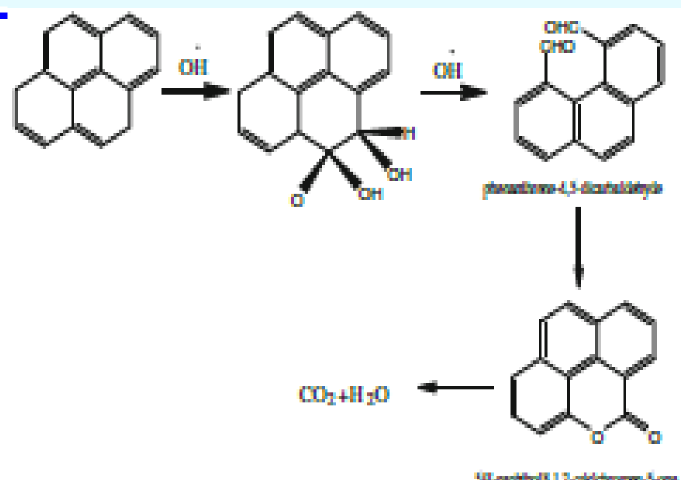


Sulfosulfuron ($t_{1/2}$ ~162 days)





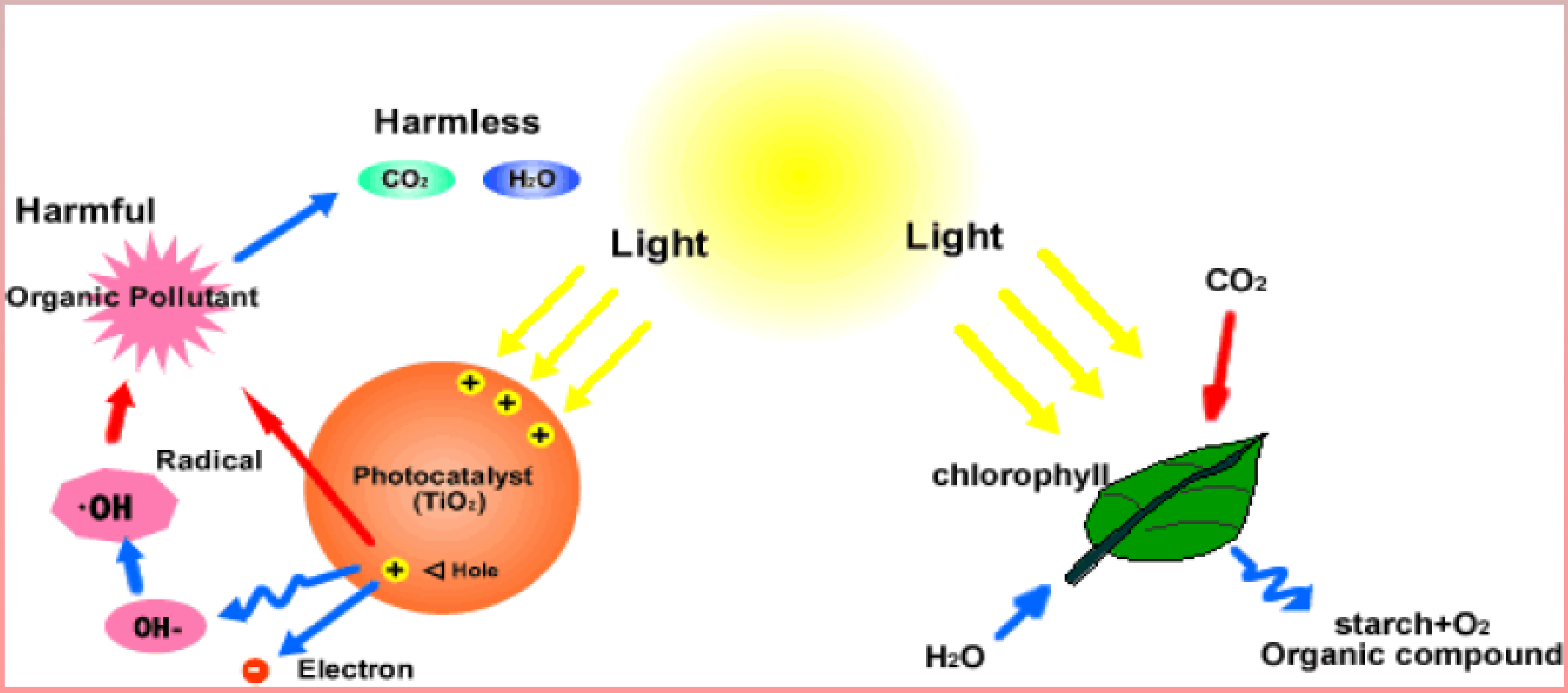
RhB



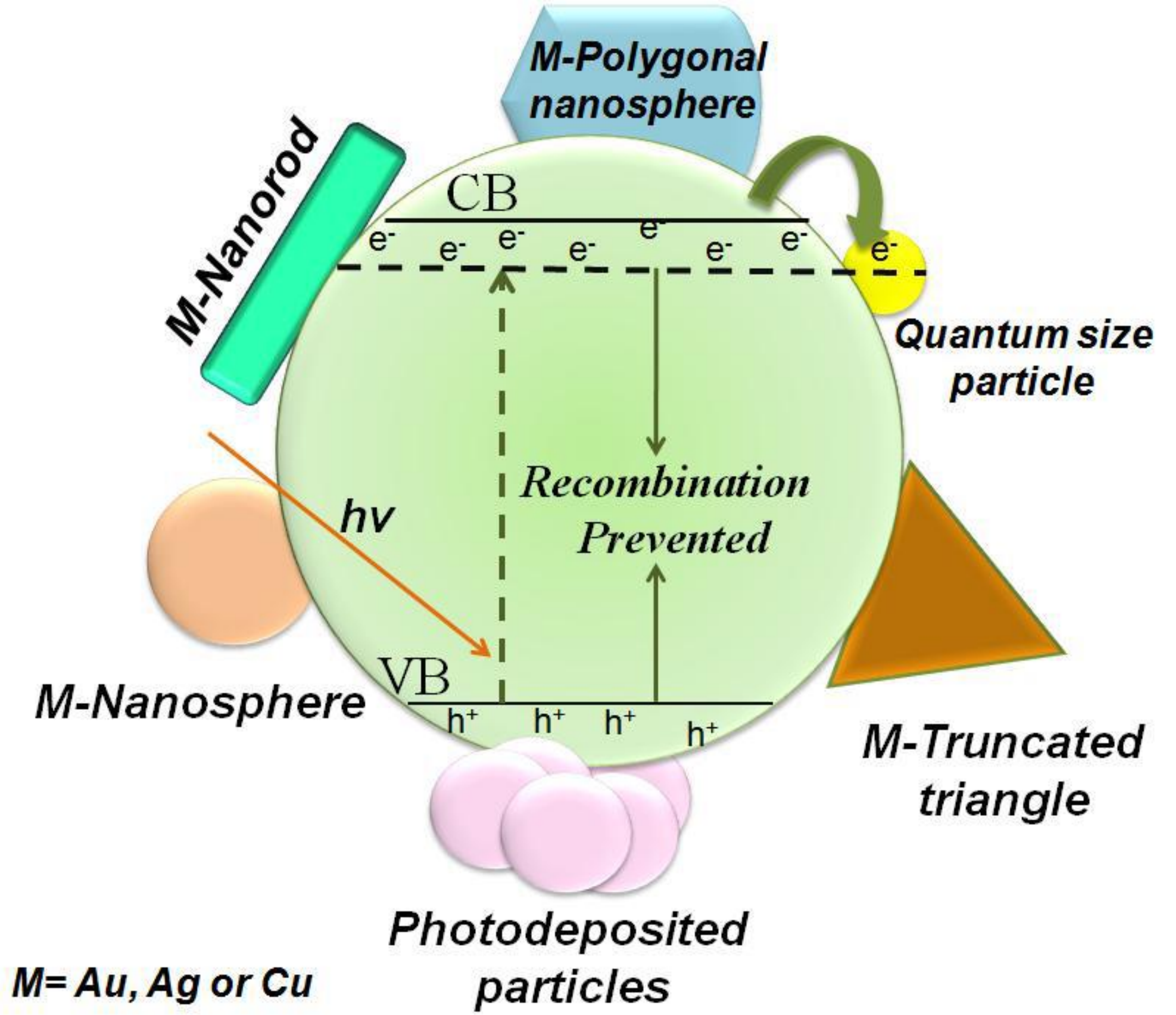
What is photocatalysts?

A substance that facilitates chemical reactions by photoirradiation without becoming transformed; e.g. Semiconductor Materials

Employing a "light-catalyst" or photocatalyst, will kick start oxidation so any germs, oils, fumes, smells, or even little algae spores which land on a surface near the photocatalyst will be burned off in a few minutes.



✓ **Metal Co-catalysis effect for TiO_2 photocatalysis**



- ➢Nature of metal effects the rate of reaction.
- ➢Each shape has its own characteristic property.
- ➢ Fermi level shift to more negative potential
- ➢ Number of TiO_2-metal junction and Interfacial contact area influence the reaction rate.
- ➢ Quick charge transfer from photocatalyst to metal co-catalyst.
- ➢ ***Preventing e^--h^+ pair recombination in varied extent.***

▪**Quantum size particles result in higher surface activity**

Au, Ag and Cu M-TiO2 photocatalysis under visible light light irradiation

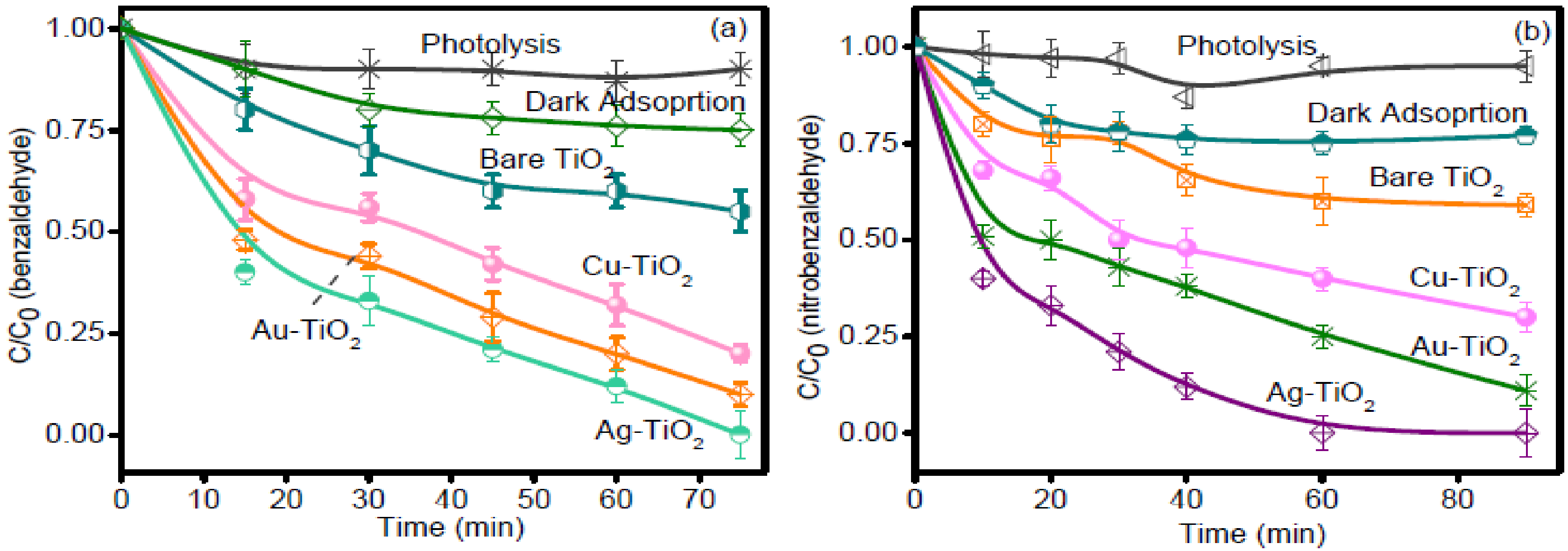


Figure 12. Time course of photodegradation of (a) benzaldehyde and (b) nitrobenzaldehyde using various M–TiO_2 composites under direct sunlight irradiation.

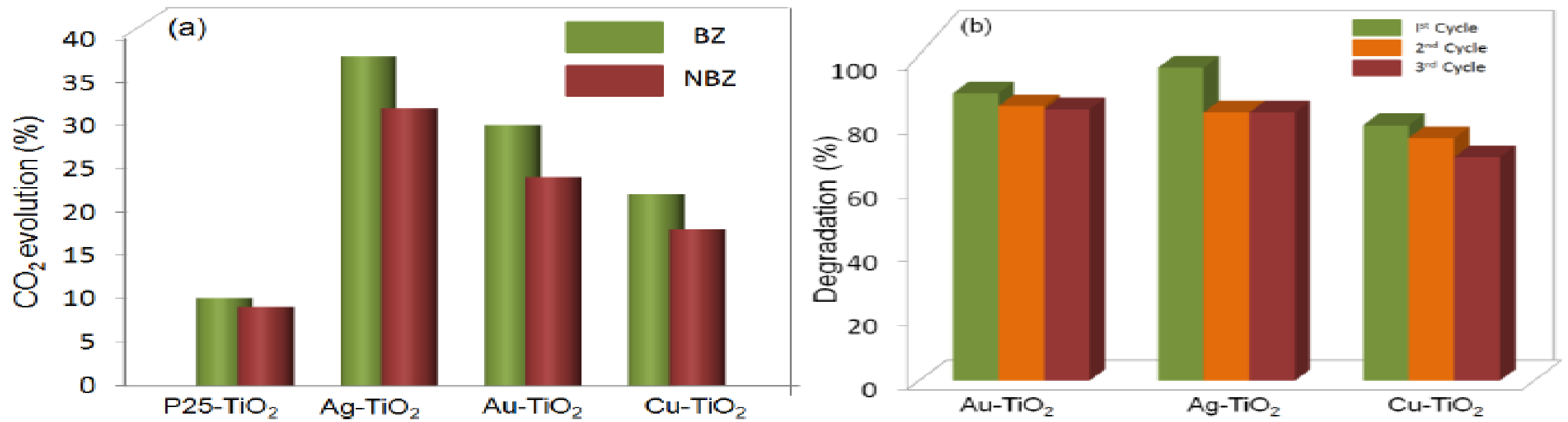
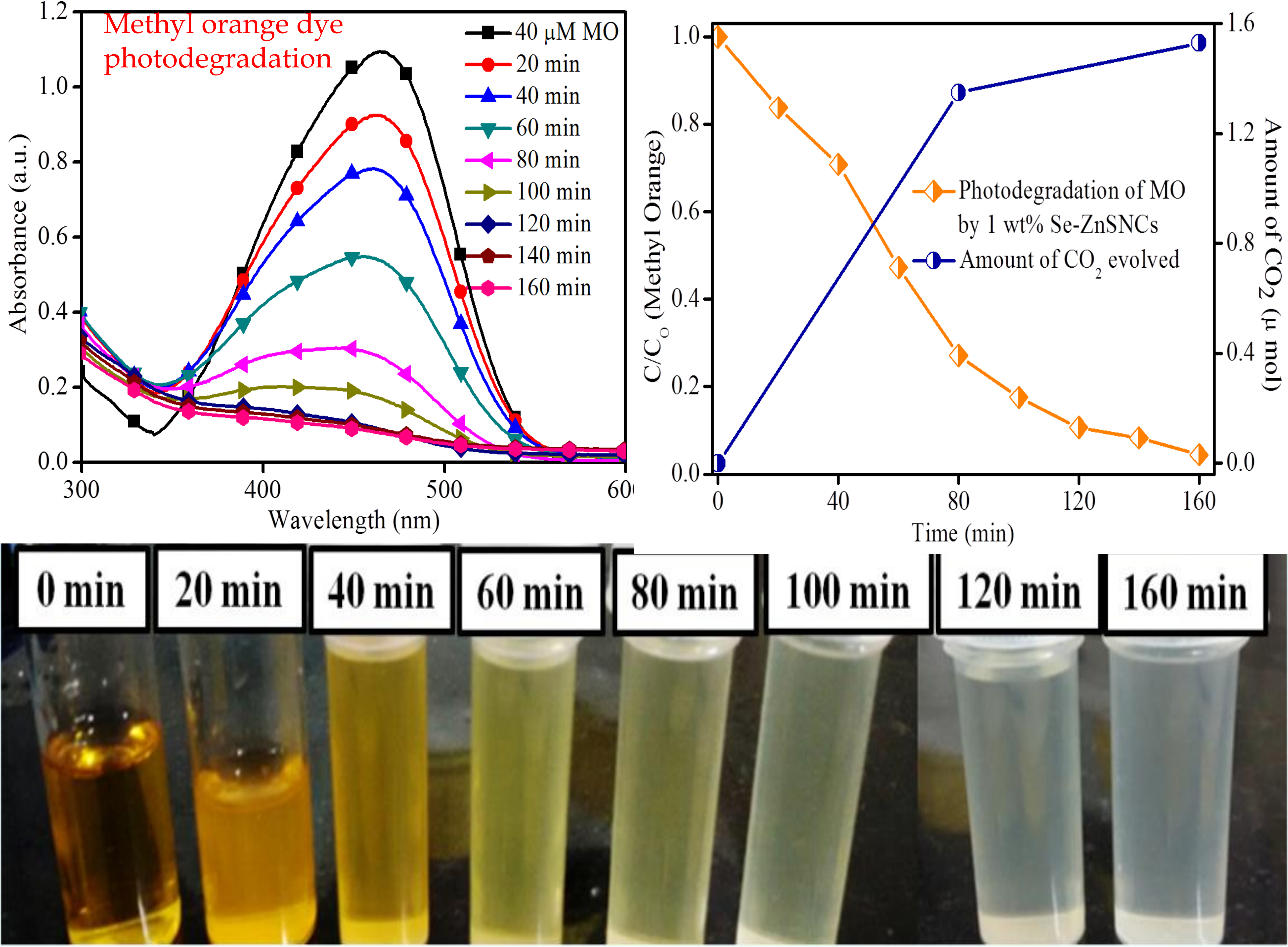
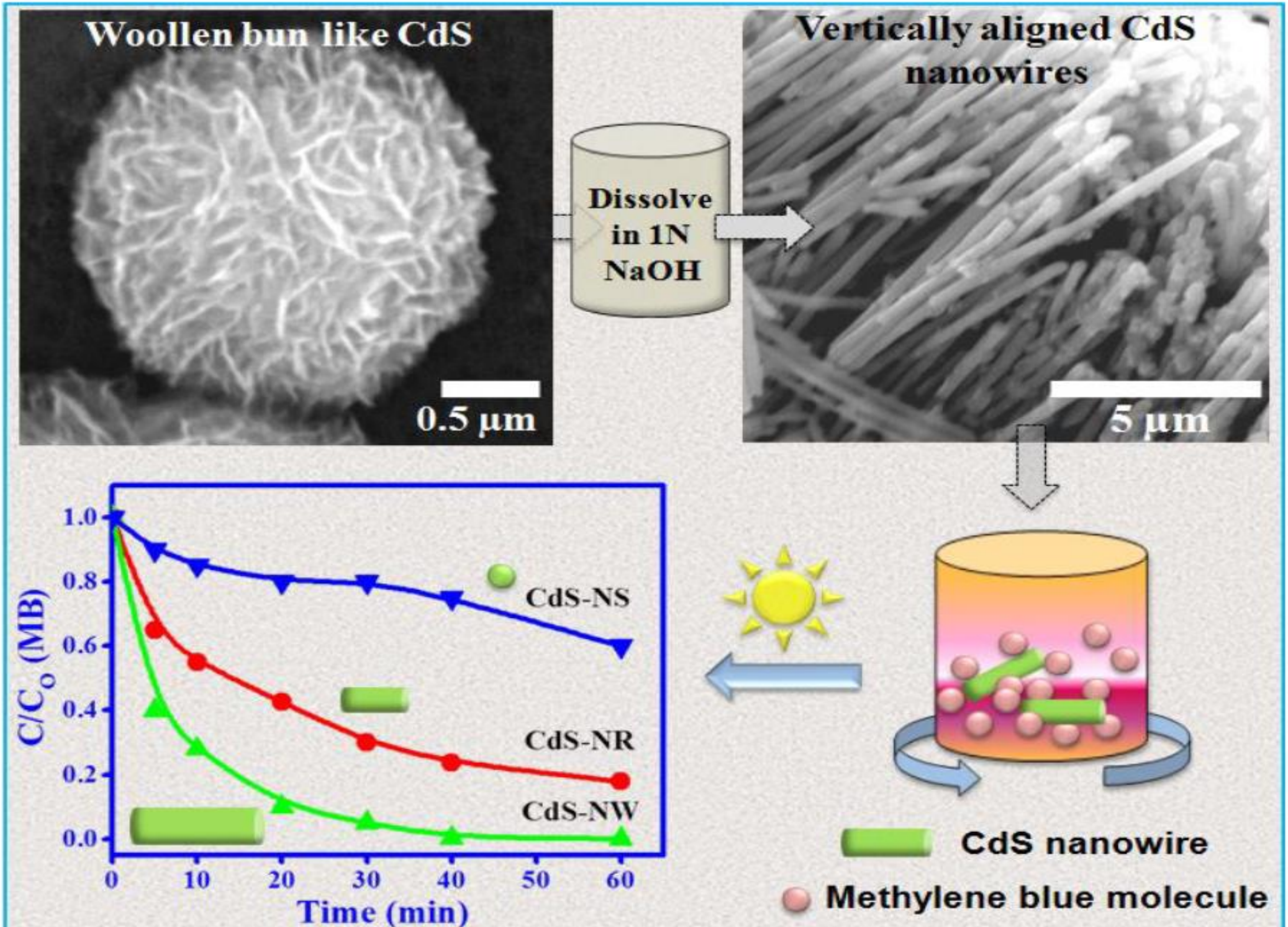


Figure 14. Percentage of CO_2 evolution on photodegradation of benzaldehyde (BZ) and nitrobenzaldehyde (NBZ) by using various M-TiO_2 nanocomposites after 3 h of sunlight irradiation and (b) nitrobenzaldehyde degradation (%) after recycling with M-TiO_2 composites under visible light irradiation.

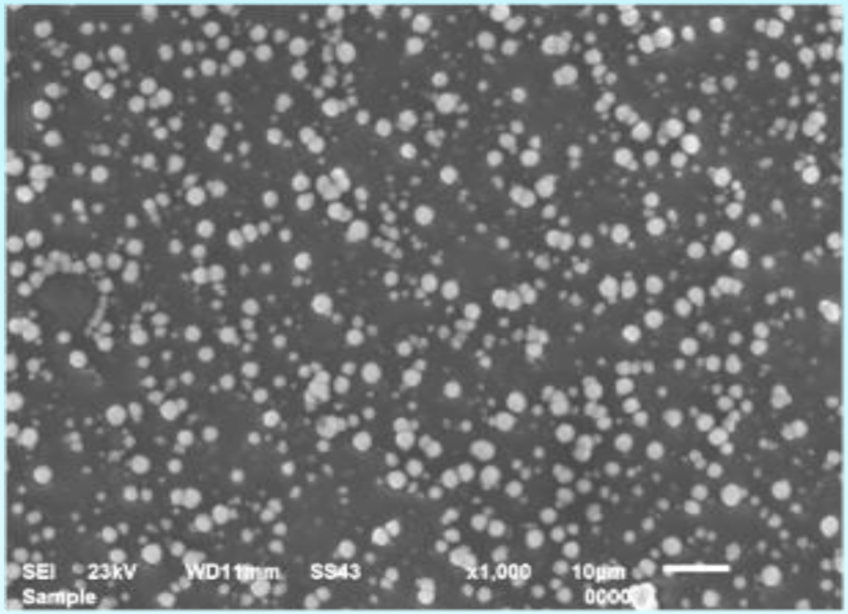


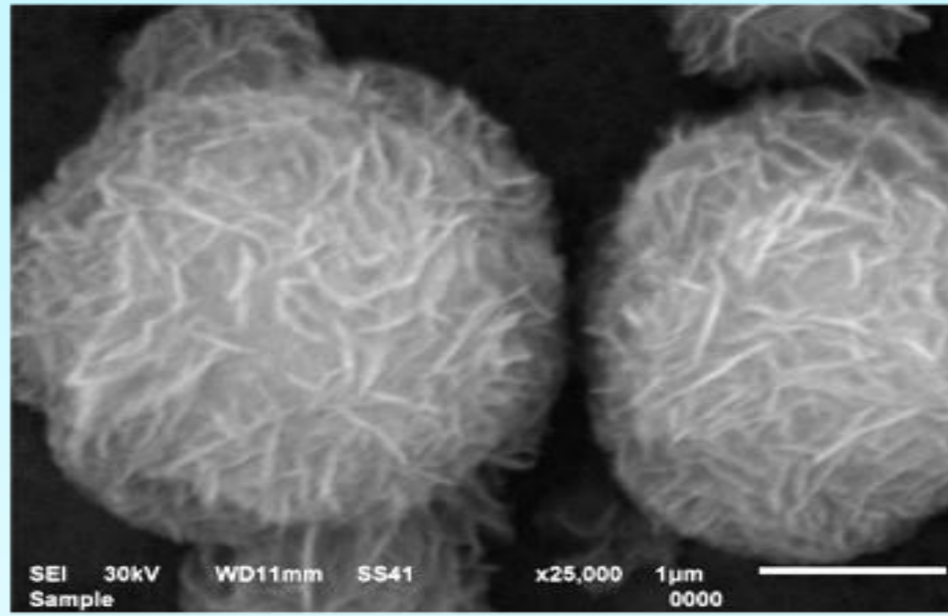
Methyl orange dye photodegradation
40 µM MO
20 min
40 min
60 min
80 min
100 min
120 min
140 min
160 min
Absorbance (a.u.)
Wavelength (nm)
C/C_O (Methyl Orange)
Amount of CO2 (µ mol)
Photodegradation of MO by 1 wt% Se-ZnSNCs
Amount of CO2 evolved
Time (min)
0 min
20 min
40 min
60 min
80 min
100 min
120 min
160 min

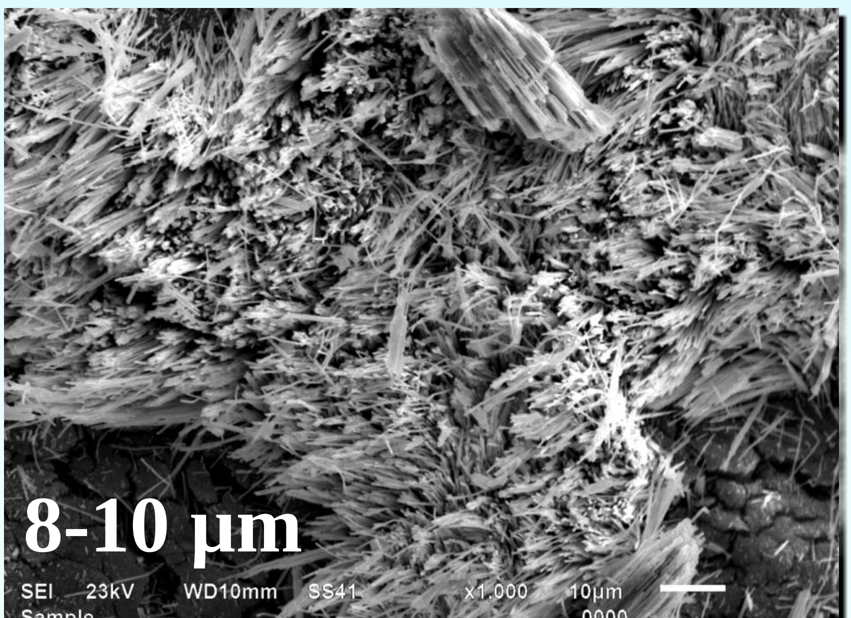


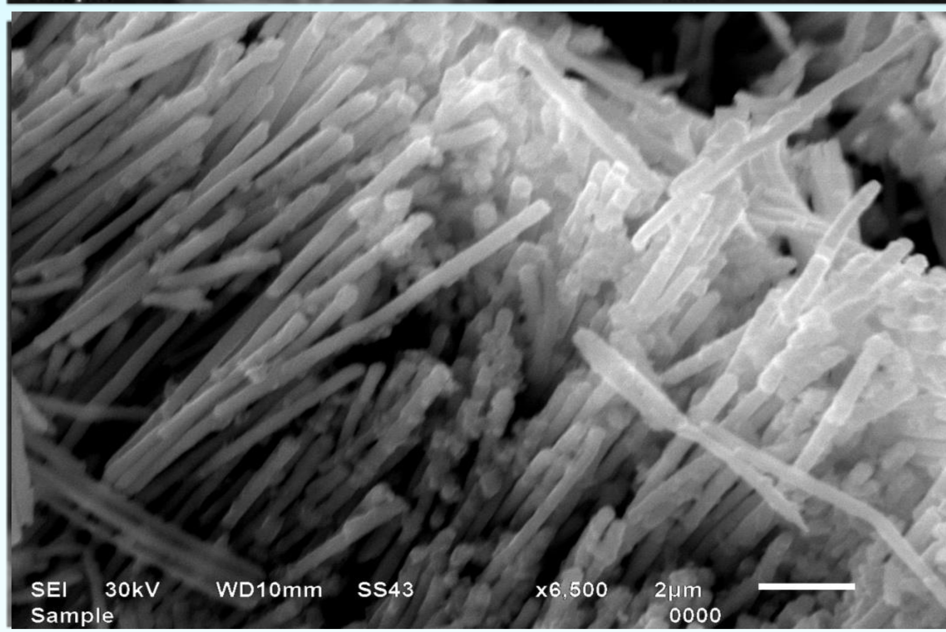
Woollen bun like CdS
0.5 µm
Dissolve in 1N NaOH
Vertically aligned CdS nanowires
5 µm
C/Co (MB)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
Time (min)
CdS-NS
CdS-NR
CdS-NW
CdS nanowire
Methylene blue molecule

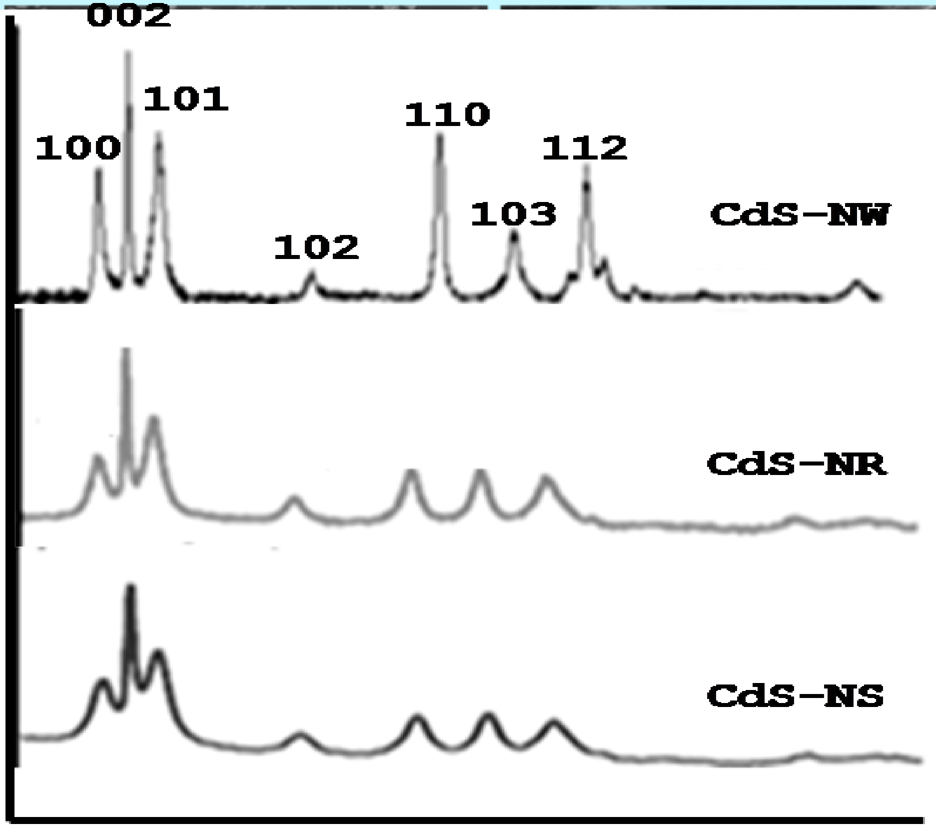
Woolen bun like microspheres **(2μm)** containing lengthy CdS nanowires for higher sun light absorption capacity and photoactivity

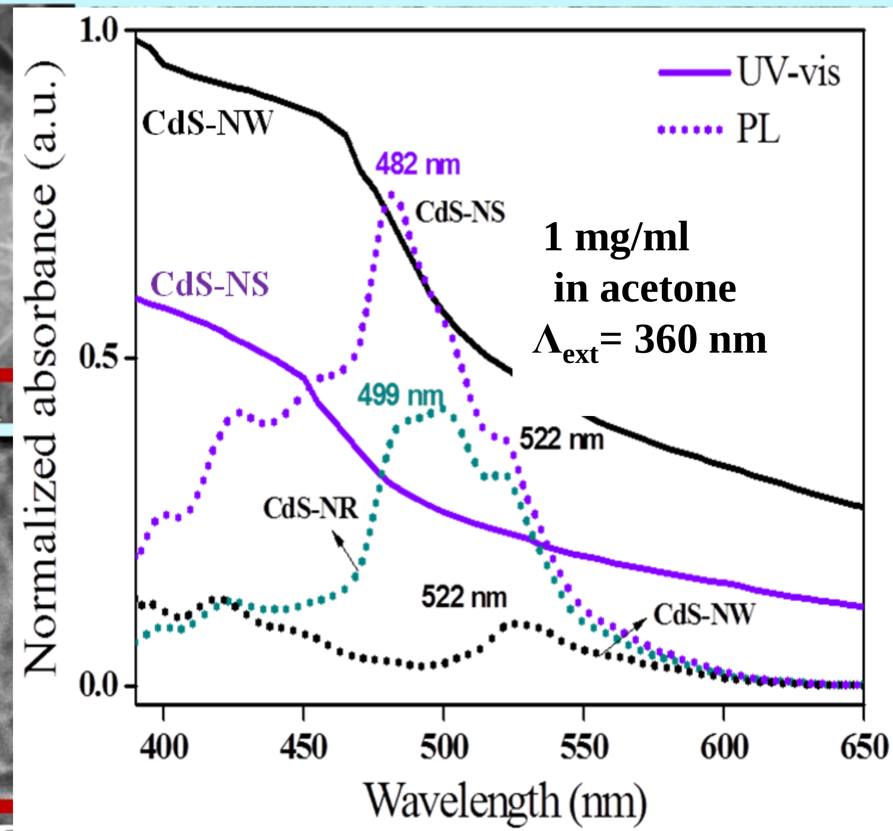


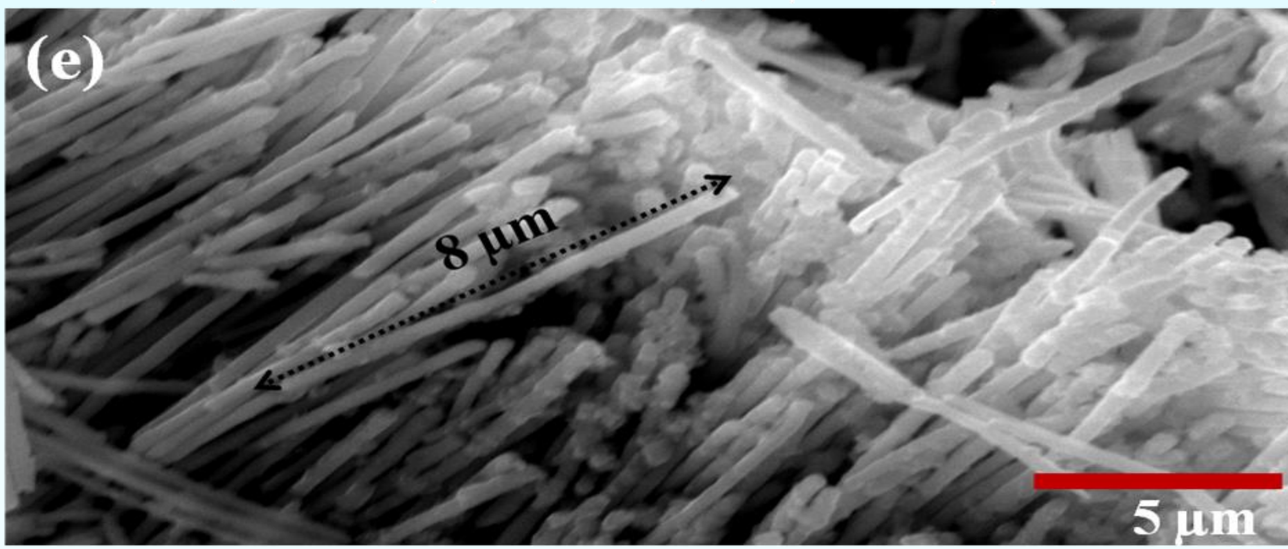


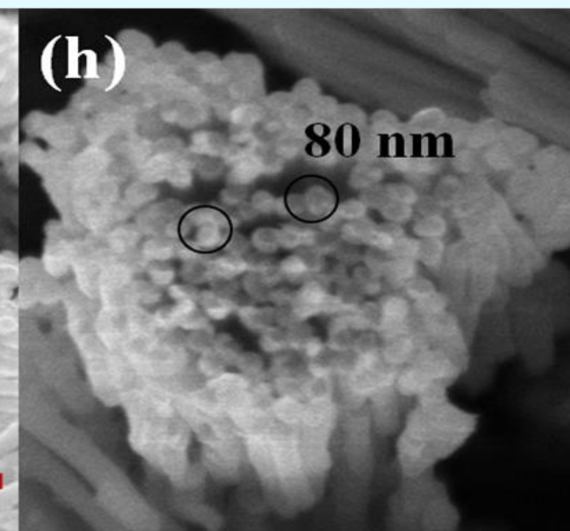




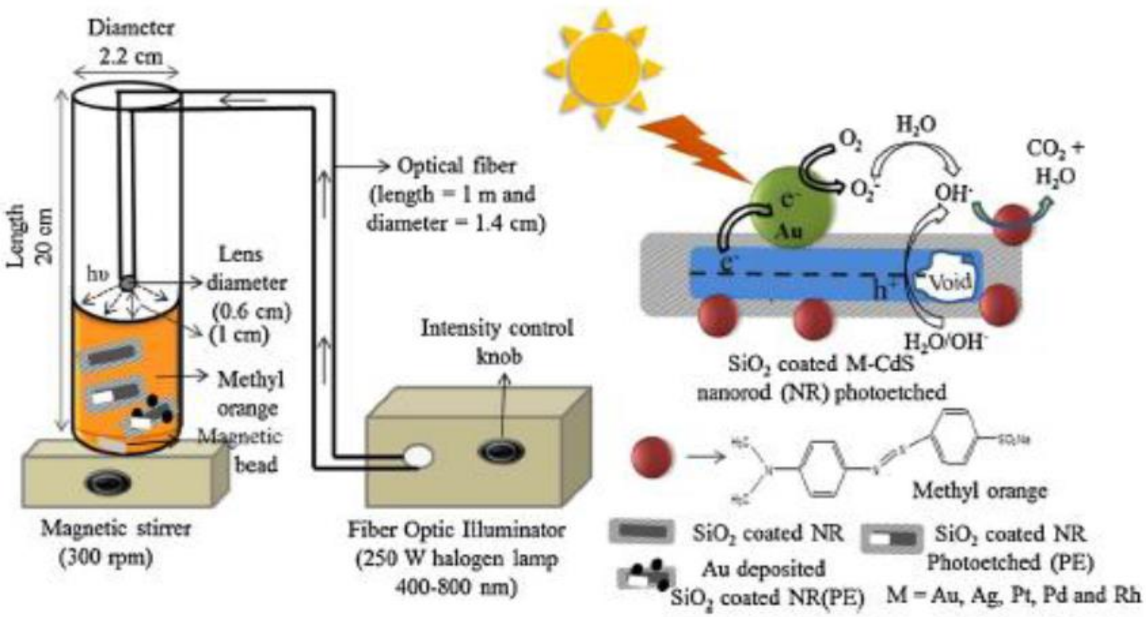

002
101
100
110
112
103
102
CdS−NW
CdS−NR
CdS−NS


UV-vis
PL
CdS-NW
482 nm
CdS-NS
1 mg/ml
in acetone
Λ_{ext}= 360 nm
CdS-NS
499 nm
522 nm
CdS-NR
522 nm
CdS-NW
Normalized absorbance (a.u.)
Wavelength (nm)
1.0
0.5
0.0
400
450
500
550
600
650


(e)
8 µm
5 µm


(h)
80 nm

N. Gupta, B. Pal / Journal of Molecular Catalysis A: Chemical 391 (2014) 158–167



Scheme 1. Photocatalytic reaction set up and mechanism for methyl orange degradation.

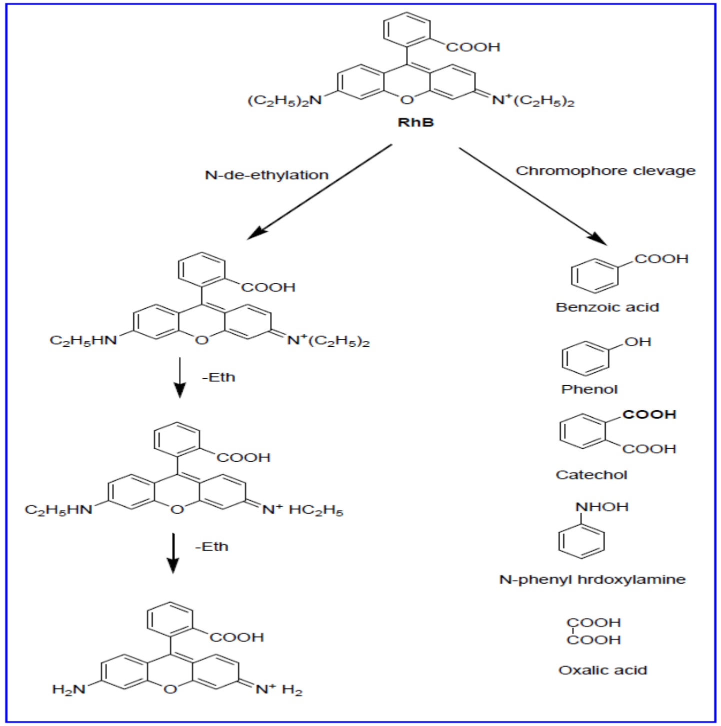
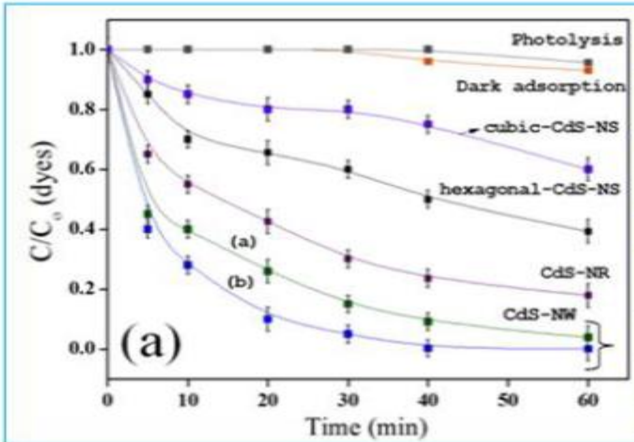


Fig. 8. Proposed degradation pathway of RhB dye with CdS-NW



m/z	Name (Chemical formula) (b)
180	4-(methoxycarbonyl) benzoic acid ($C_9H_8O_4$)
147	Isoindoline-1,3-dione ($C_8H_5NO_2$)
122	Benzoic acid ($C_7H_6O_2$)
110	Pyrocatechol ($C_6H_6O_2$)
109	N-phenyl hydroxylamine (C_6H_5NHOH)
94	Phenol (C_6H_5OH)
92	Propane-1,2,3-triol ($C_3H_8O_3$)
90	Oxalic acid ($C_2H_2O_4$)

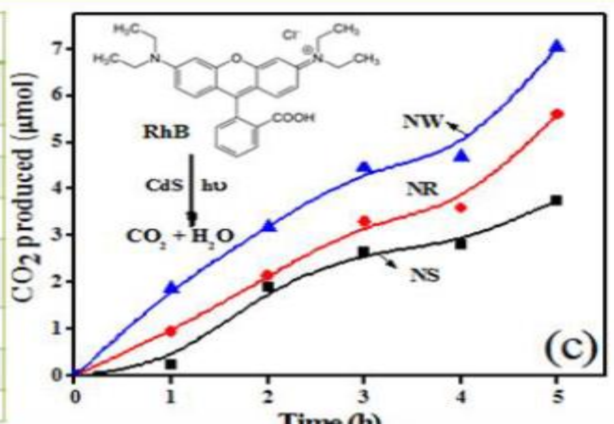
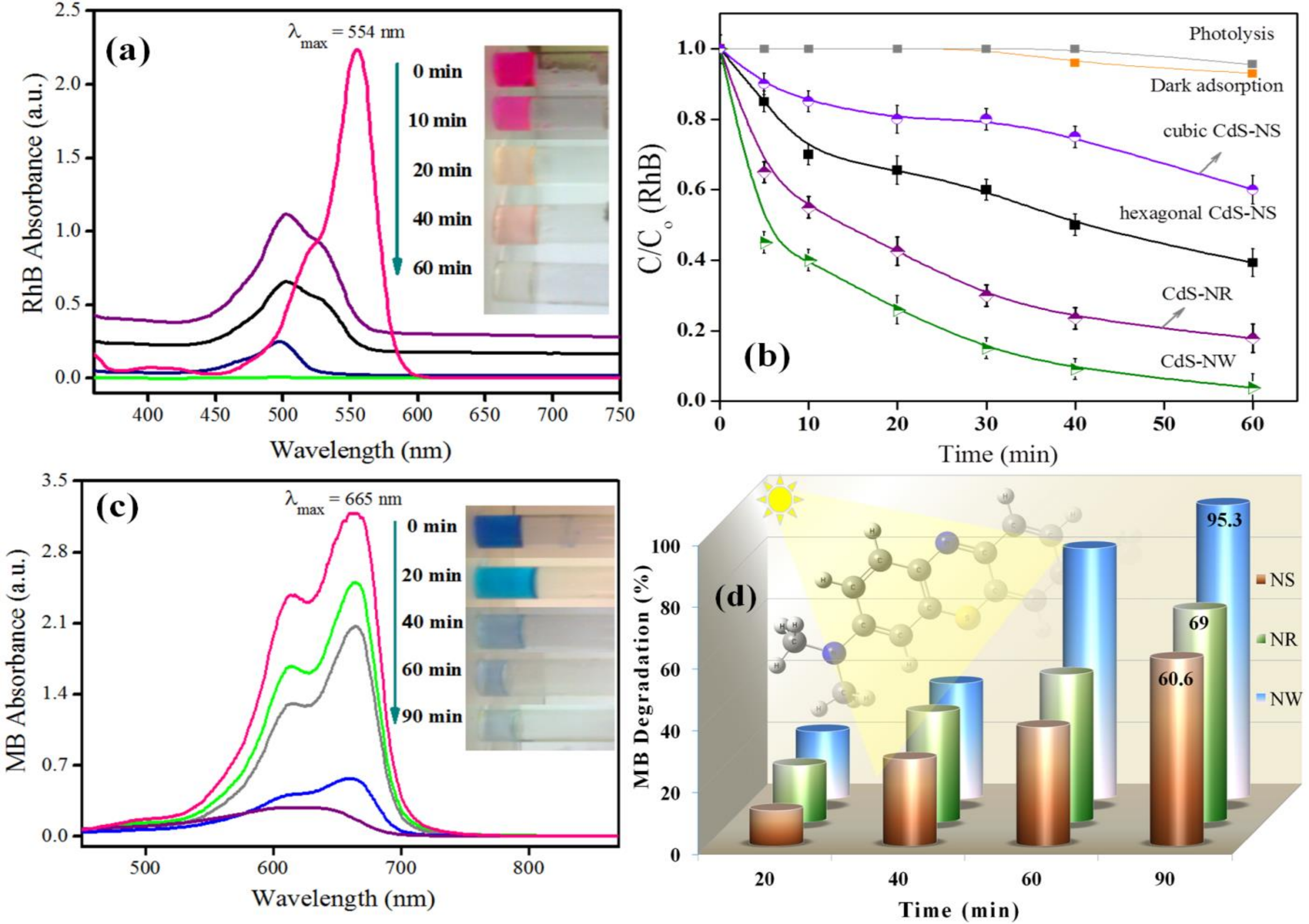
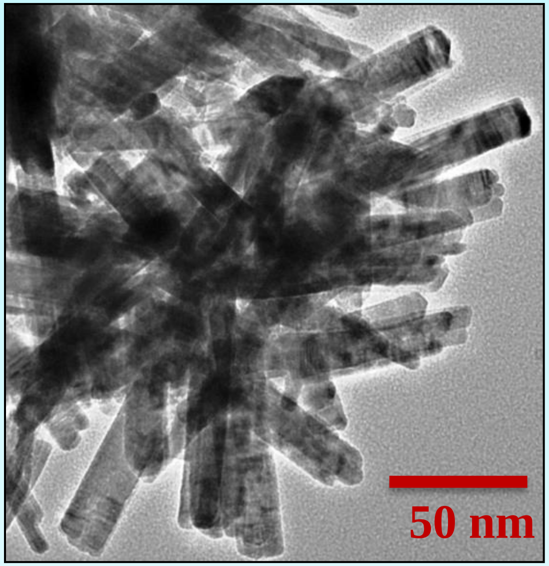


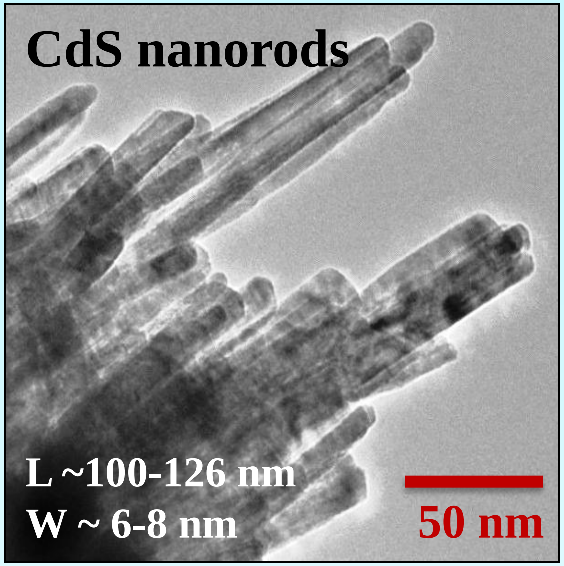
Fig. 7. (a) C/C_o Plots versus irradiation time of (a) RhB and (b) MB (10 ml, 5×10^{-5} mol L^{-1}) degradation (b) identified intermediates of RhB decomposition by GC-MS analysis and (c) time course of CO_2 evolution during RhB degradation with various CdS nanostructures (2 mg) under sunlight exposure.

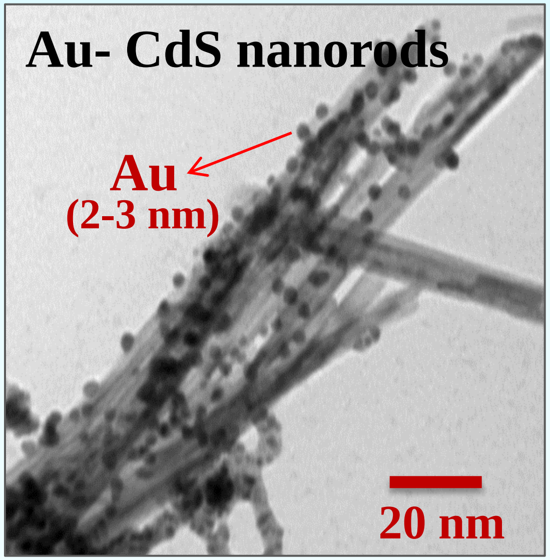


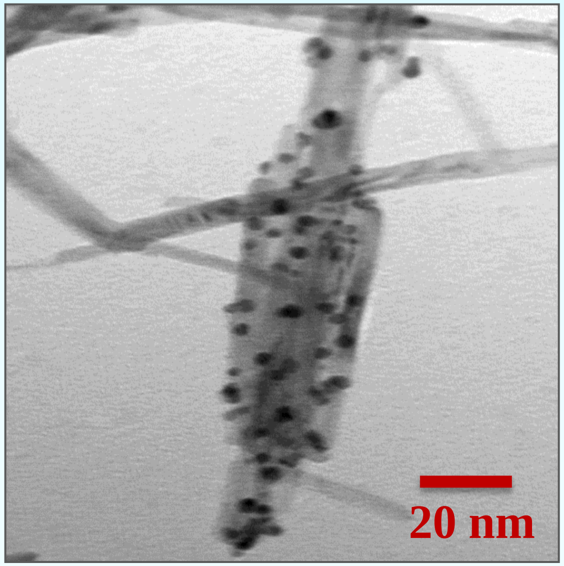
(a)
λ_{max} = 554 nm
0 min
10 min
20 min
40 min
60 min
RhB Absorbance (a.u.)
Wavelength (nm)
(b)
Photolysis
Dark adsorption
cubic CdS-NS
hexagonal CdS-NS
CdS-NR
CdS-NW
C/C$_o$ (RhB)
Time (min)
(c)
λ_{max} = 665 nm
0 min
20 min
40 min
60 min
90 min
MB Absorbance (a.u.)
Wavelength (nm)
(d)
NS
NR
NW
95.3
69
60.6
MB Degradation (%)
Time (min)

Metal (Au, Ag & Cu) –CdS composites for high photoactivity under sunlight exposure for degradation of salicylic acid

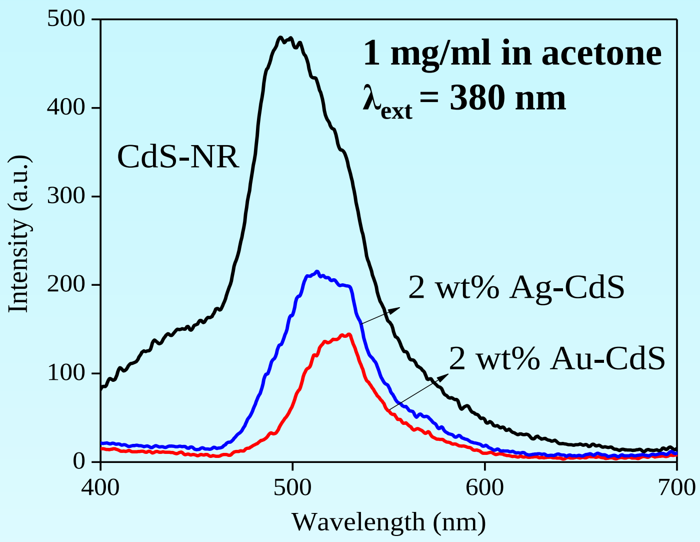




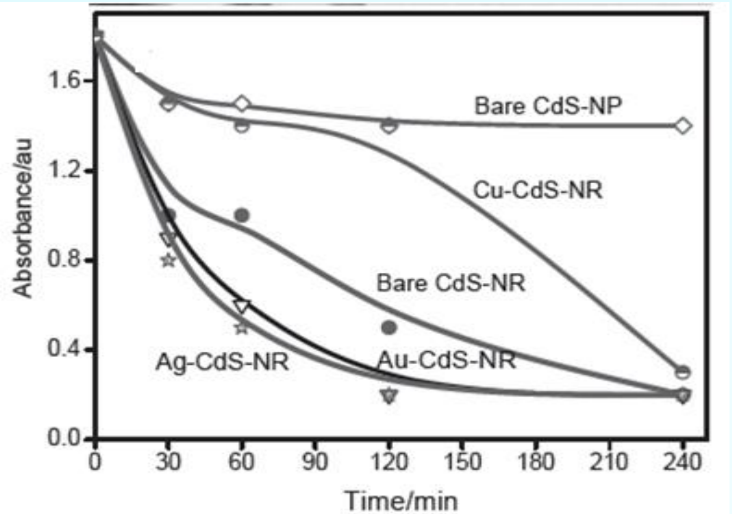




Photoluminescence Spectra

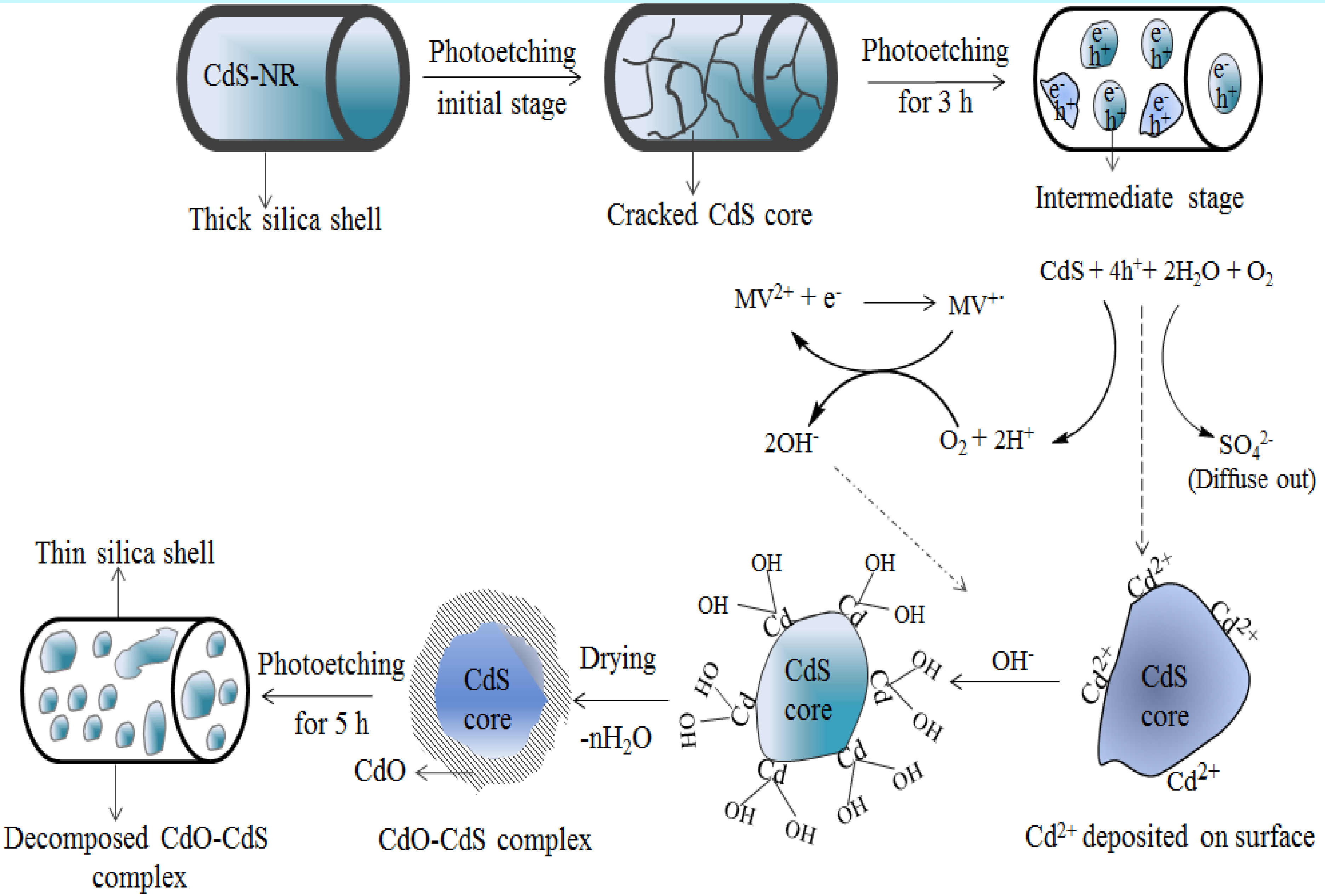


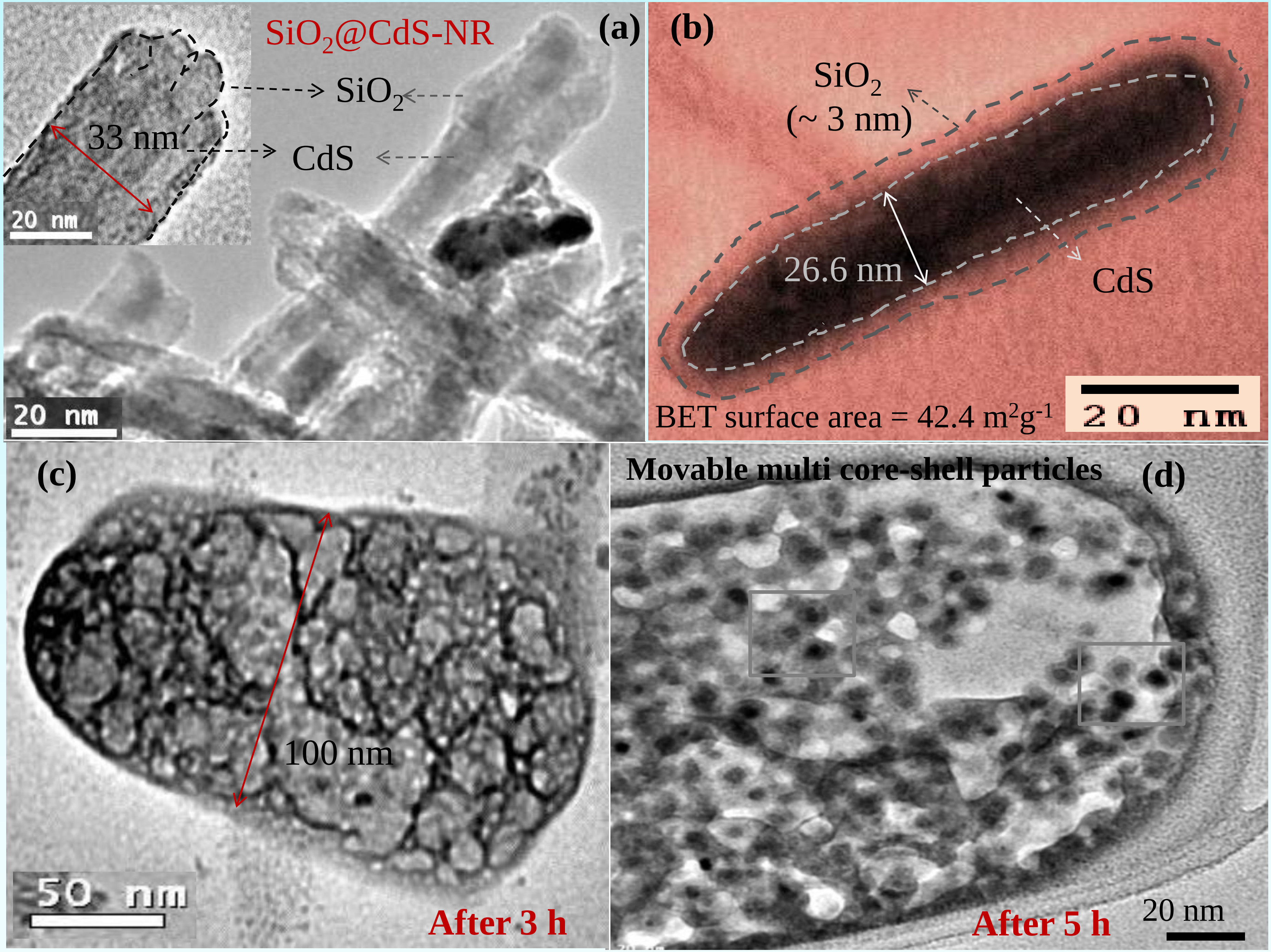
Salicylic acid degradation (0.5 mM)



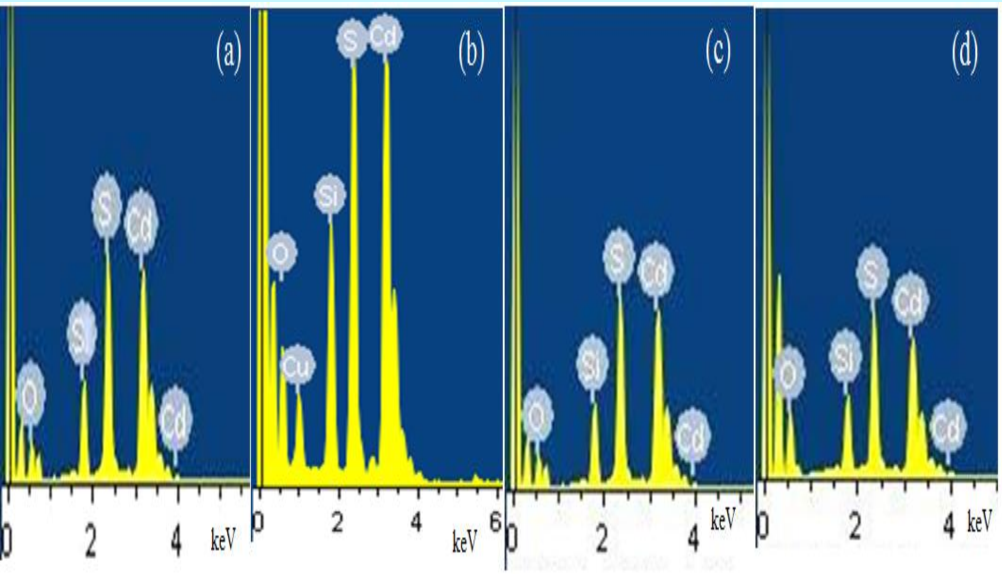
Rohit Singh and Bonamali Pal, "*Enhanced photocatalytic activity of coinage metal-CdS nanorod composites under sunlight irradiation*, accepted in Advance Materials Research (2012).

Movable CdO@CdS core-shell nanostructures in lengthy SiO_2 matrix



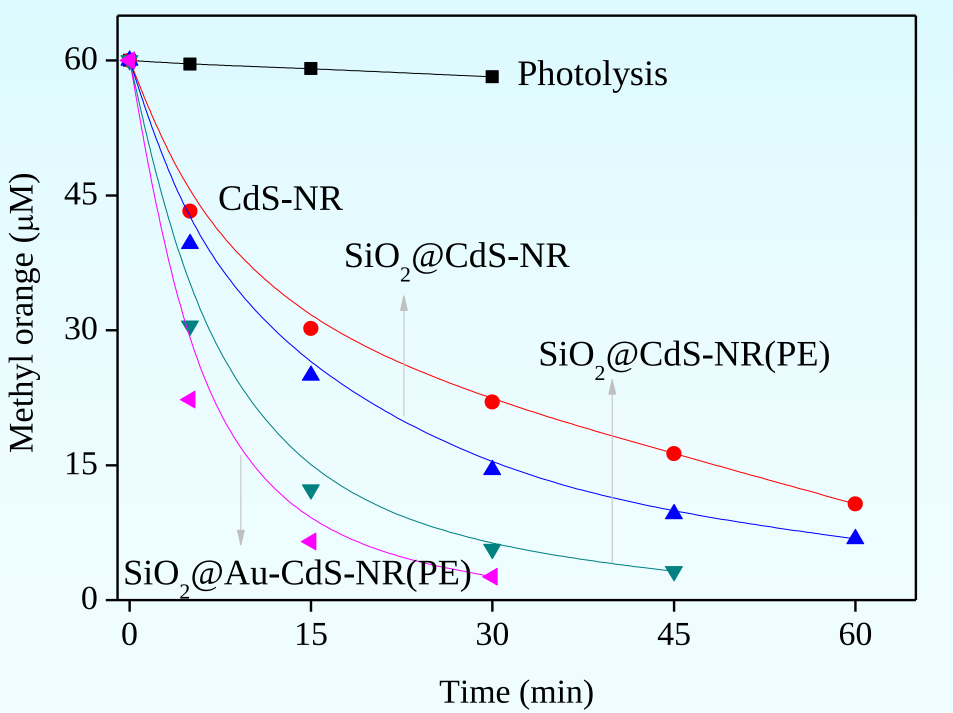


SiO2@CdS-NR
(a)
SiO2
CdS
33 nm
20 nm
20 nm
(b)
SiO2
(~ 3 nm)
26.6 nm
CdS
BET surface area = 42.4 m2g-1
20 nm
(c)
100 nm
50 nm
After 3 h
Movable multi core-shell particles
(d)
After 5 h
20 nm

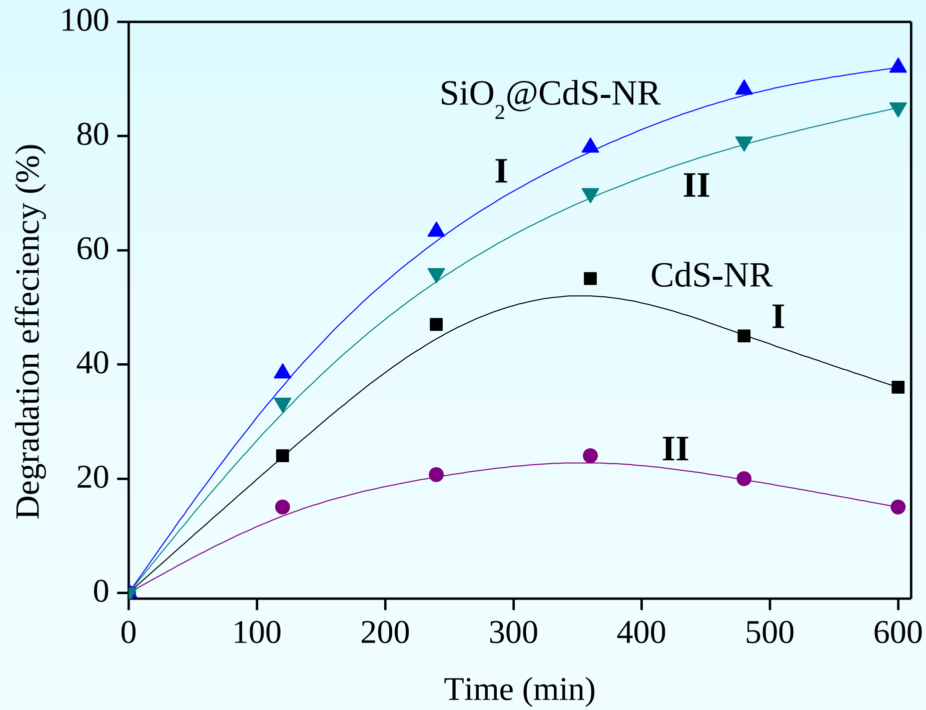


Sample	Cd (at%)	S (at%)	Si (at%)	O (at%)	Cu (at%)	Total
(a)Bare CdS-NR	36.63	40.57	-	5.07	17.73	100.00
(b) SiO_2@CdS-NR	19.79	22.90	12.81	17.81	26.69	100.00
(c) SiO_2@CdS-NR(PE) after 3 h	14.62	17.12	9.57	38.15	20.54	100.00
(d) SiO_2@CdS-NR(PE) after 5 h	8.77	11.61	7.47	49.47	22.68	100.00

Photodegradation of Methyl orange (60 μM)



Reusability test for MO (0.6 mM)



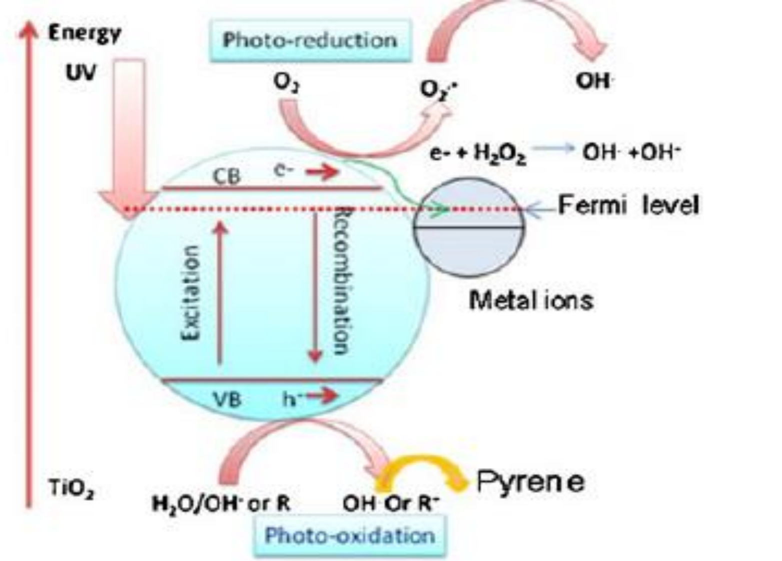
Superior photodecomposition of pyrene by metal ion-loaded TiO_2 catalyst under UV light irradiation

Malka Rani, Nidhi Gupta & Bonamali Pal

Environmental Science and Pollution Research

ISSN 0944-1344
Volume 19
Number 6

Environ Sci Pollut Res (2012)
19:2305-2312
DOI 10.1007/s11356-012-0739-x



Scheme 1 Mechanism of pyrene decomposition at the metal ions–TiO_2 interface under UV light irradiation

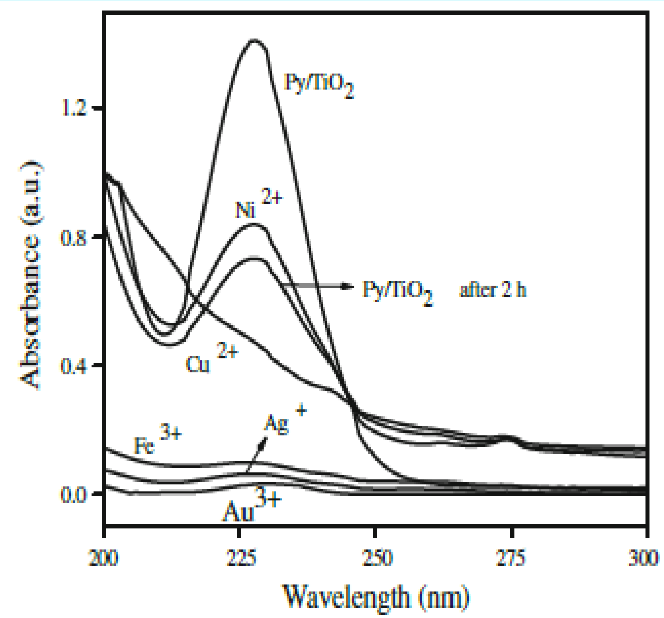
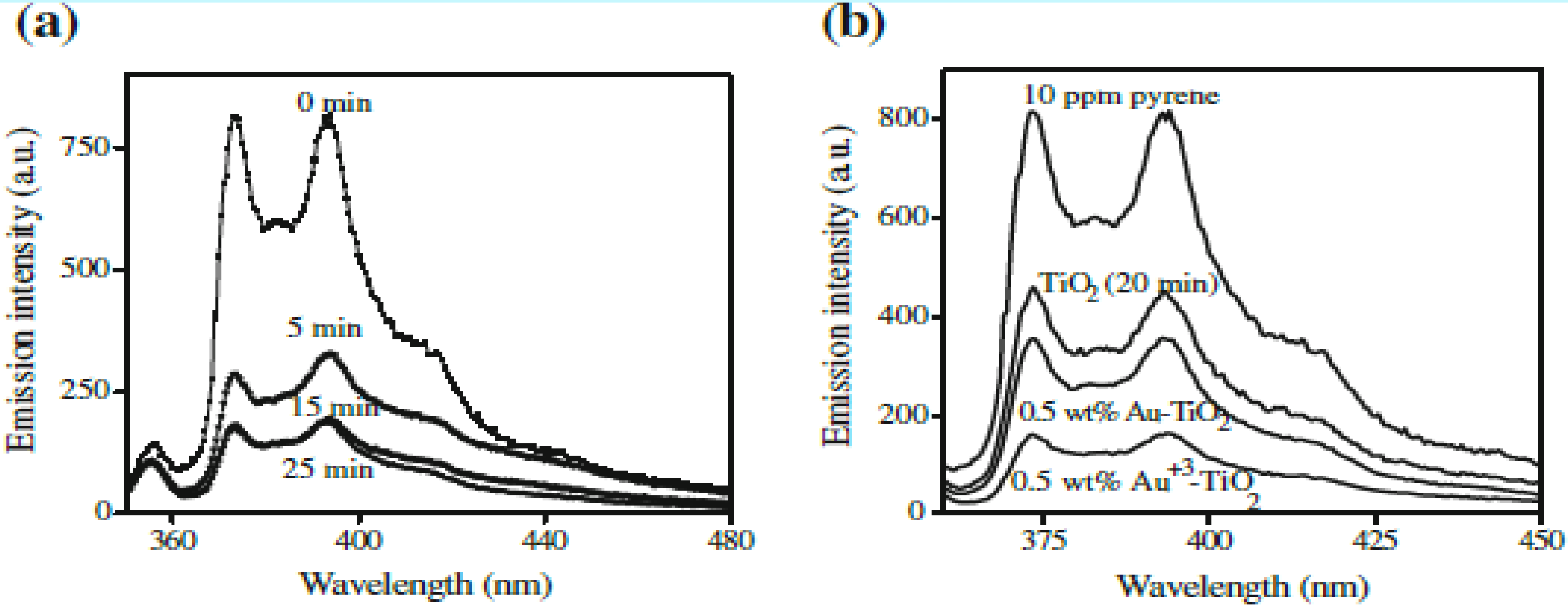
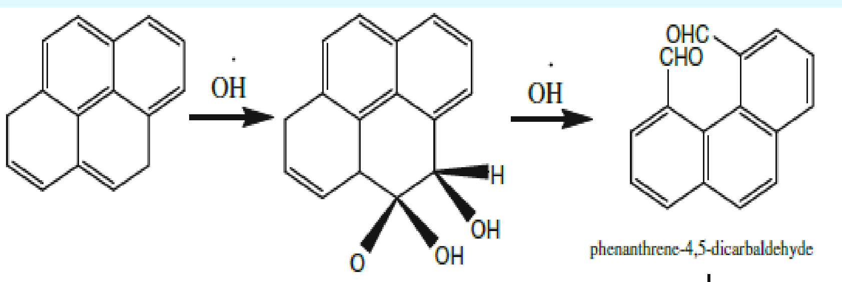
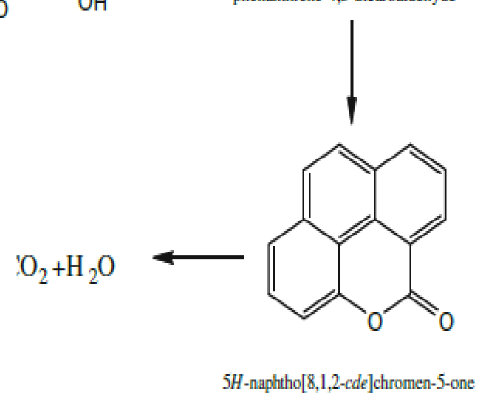


Fig. 4 Effect of dissolved transition metal ions (100 μmol) on the photocatalytic degradation of preadsorbed pyrene–TiO_2 under 2 h light irradiation







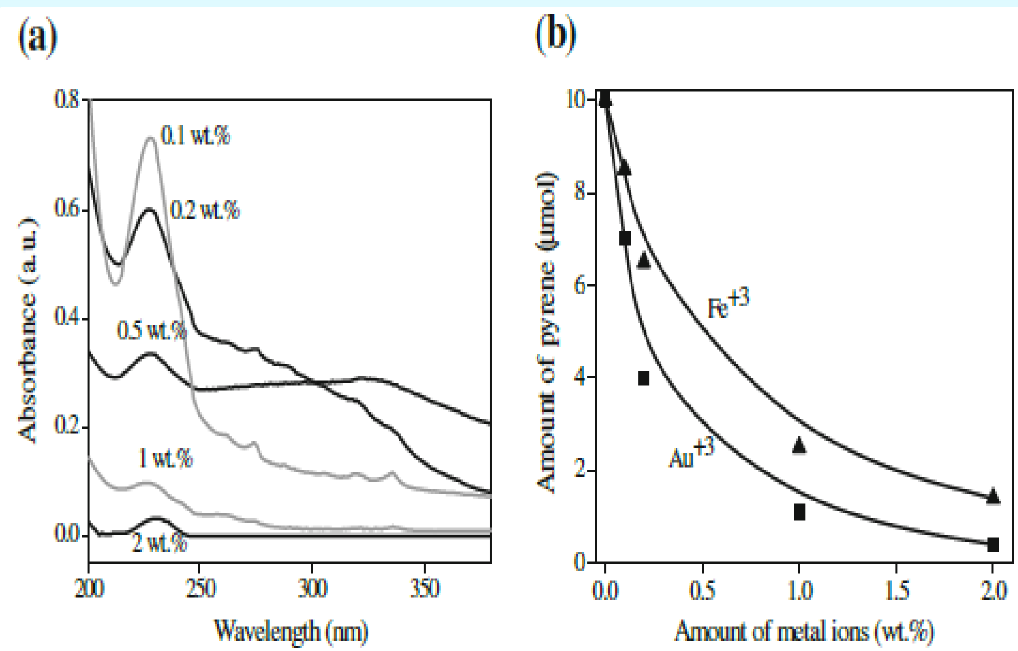
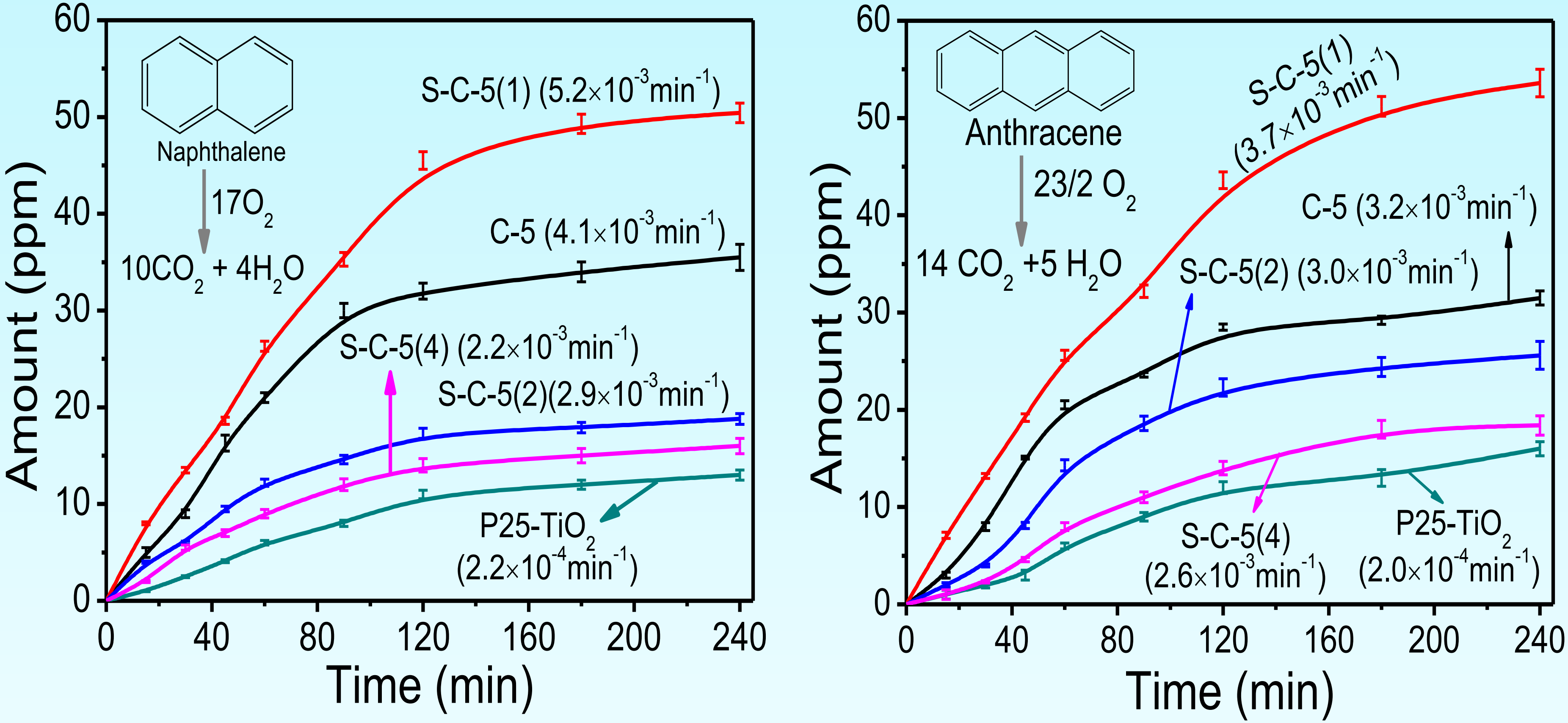


Fig. 1 Photocatalytic degradation of preadsorbed pyrene–TiO_2 at different time of light irradiation: a Changes in absorption spectra and b fluorescence spectra

Estimation for CO_2 formation



Mineralization found after 240 min:

(i) 73.0 % for Naphthalene

(ii) 78.2% for Anthracene

Rapid photokilling of gram-negative *Escherichia coli* bacteria by platinum dispersed titania nanocomposite films

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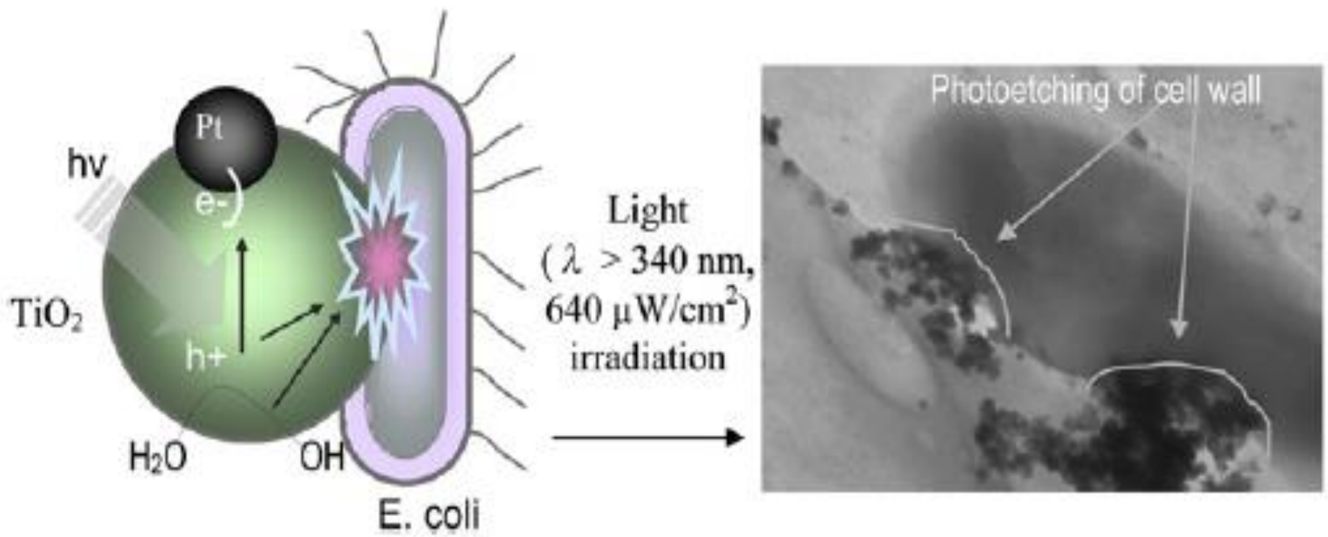
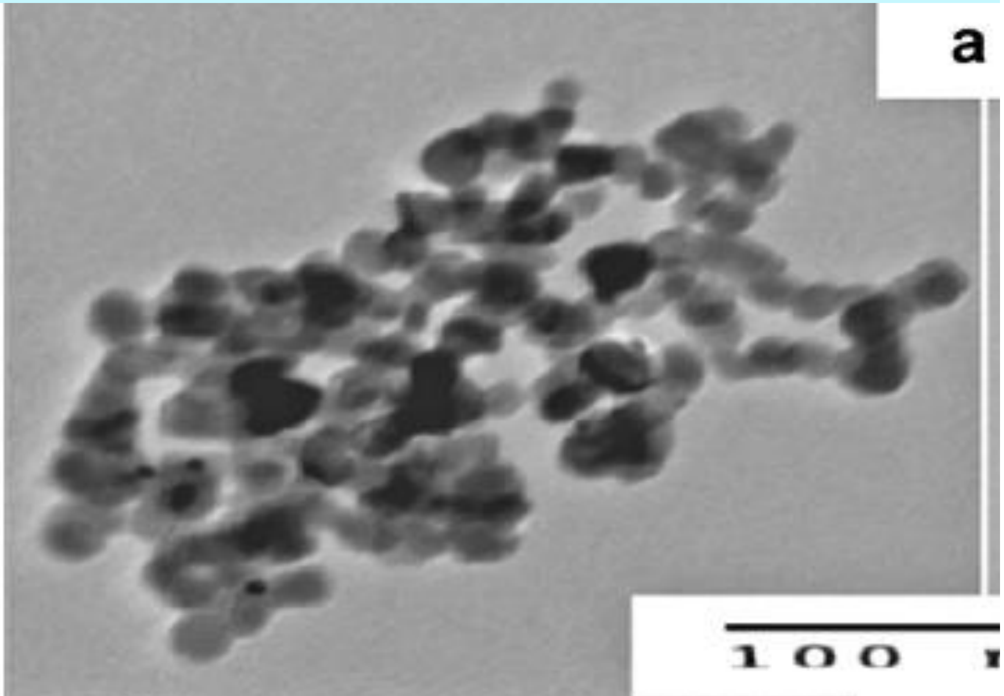
[a] *School of Chemistry and Biochemistry, Thapar University, Patiala 147004, India*
[b] *Department of Biotechnology and Environmental Sciences, Thapar University, Patiala 147004, India*

HIGHLIGHTS

- Remarkable antimicrobial activity of photorradiated Pt–TiO_2 coated thin film.
- Pt impregnation-exhibits superior photoactivity than Pt photo-deposition onto TiO_2.
- Photokilling of *E. coli* cells occur within 10 min of UV (640 μW cm^{-2}) irradiation.
- Size and nature of Pt deposition control the bactericidal effect of TiO_2 catalyst.
- Photodissolution of bacterial surface is occurred on prolong UV light exposure.

GRAPHICAL ABSTRACT





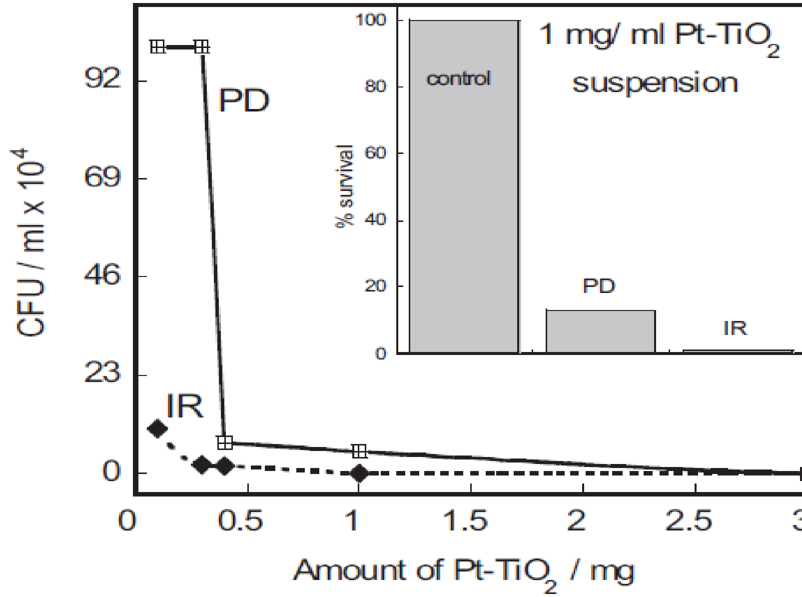
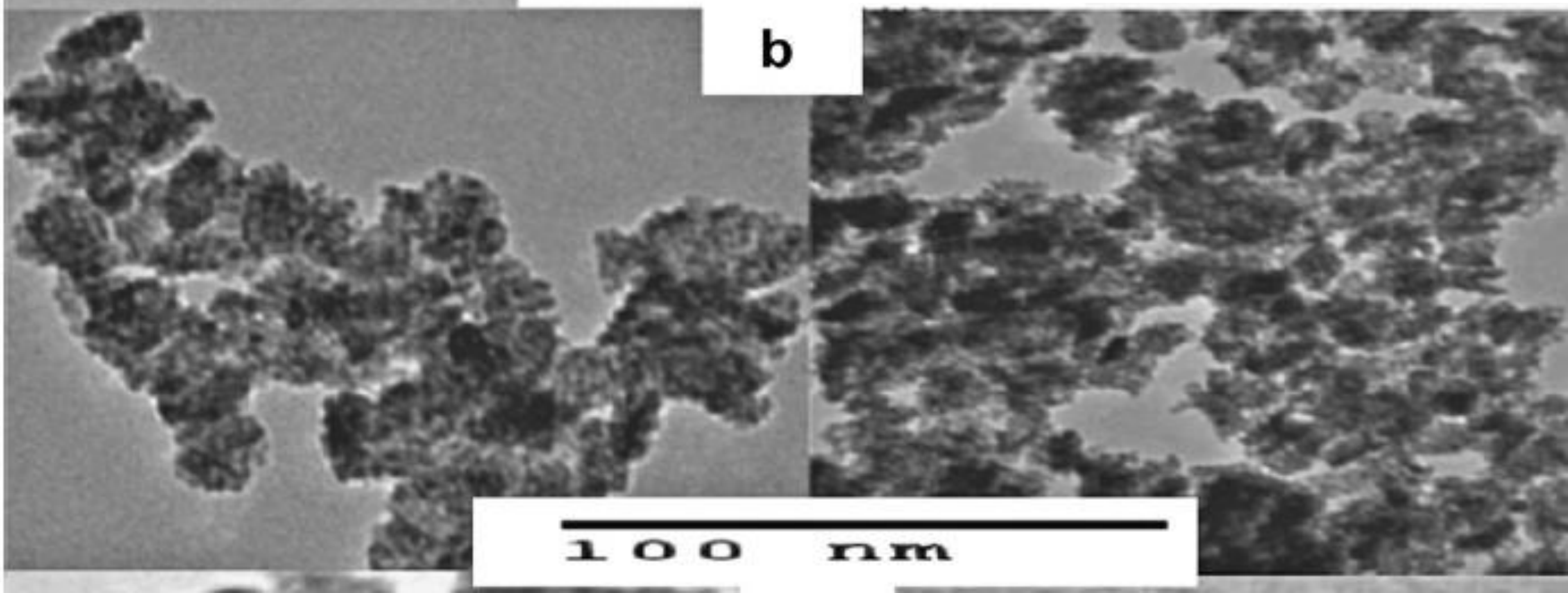


Fig. 4. Effect of the amount of Pt–TiO_2 (PD & IR) catalysts on the biocidal action of various films. *Inset*: Comparative antimicrobial activity of Pt–TiO_2 (PD & IR) catalysts powders in aqueous (5 ml) suspension after 10 min irradiation.



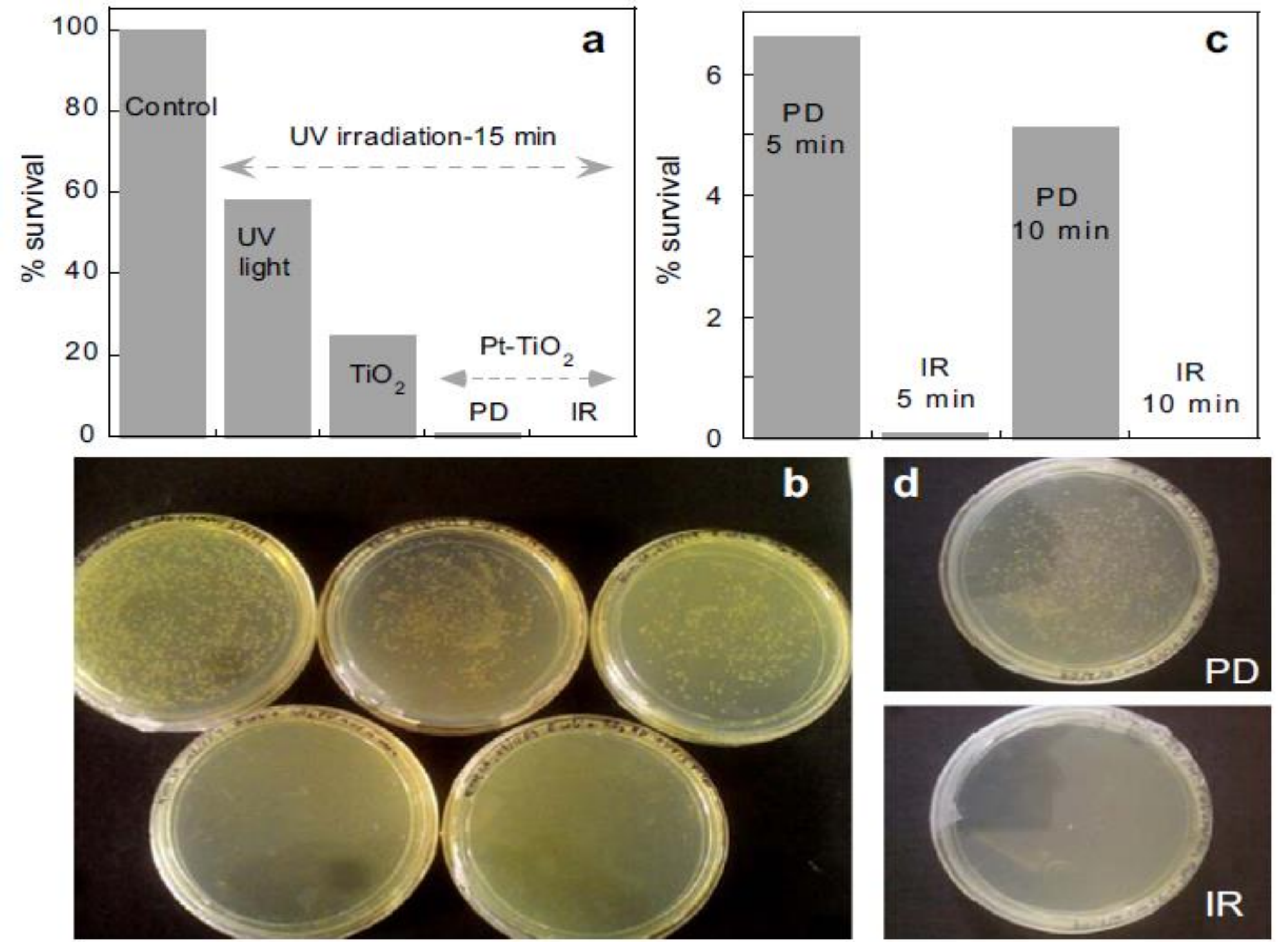
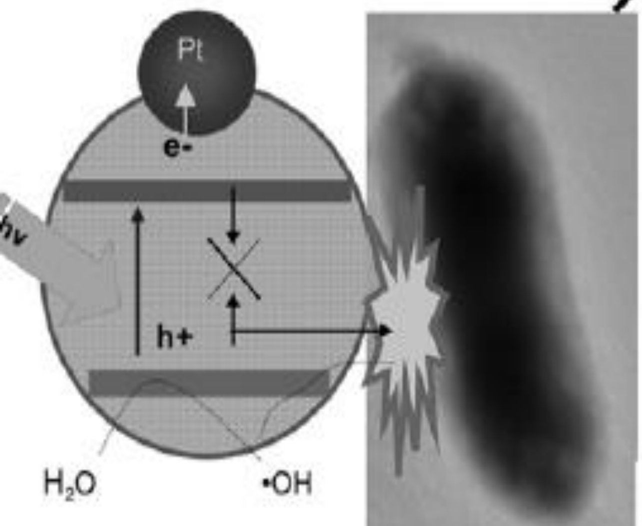
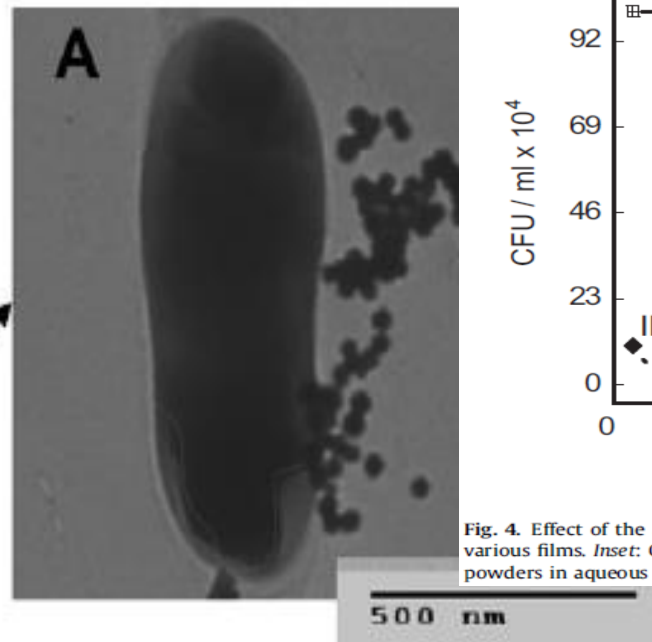


Fig. 3. (a) Bactericidal activity of bare TiO_2 and Pt–TiO_2 (PD & IR) films (5 mg catalysts) after 15 min light irradiation compared with control and UV exposure only, (b) gradual decrease (left to right plate) in bacterial colonies in sequence of Fig. 1a experimental results, (c) % cell survival after 5 and 10 min irradiation on Pt–TiO_2 (PD & IR) films, (d) disparity in colony counts after 5 min irradiation over Pt–TiO_2 (PD & IR) films as found in Fig. 1c experiment.





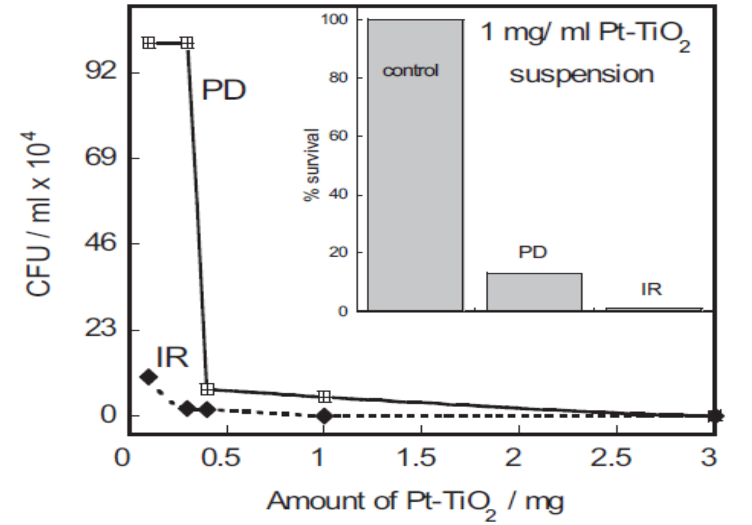
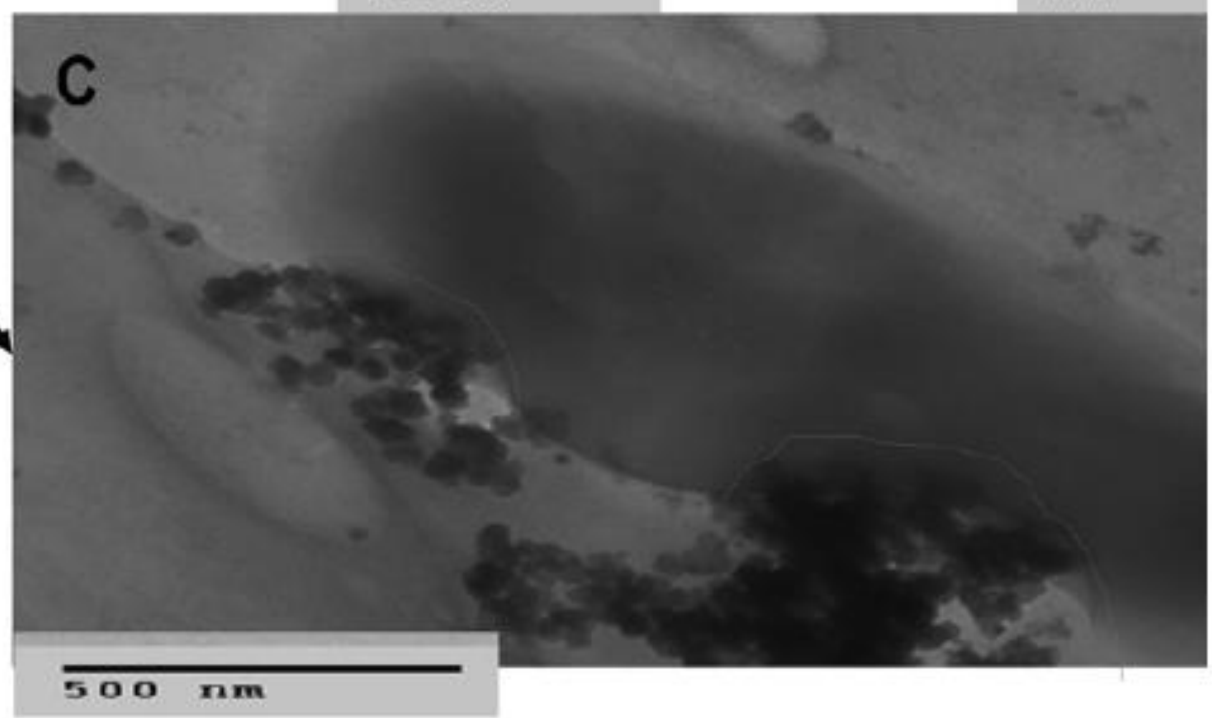
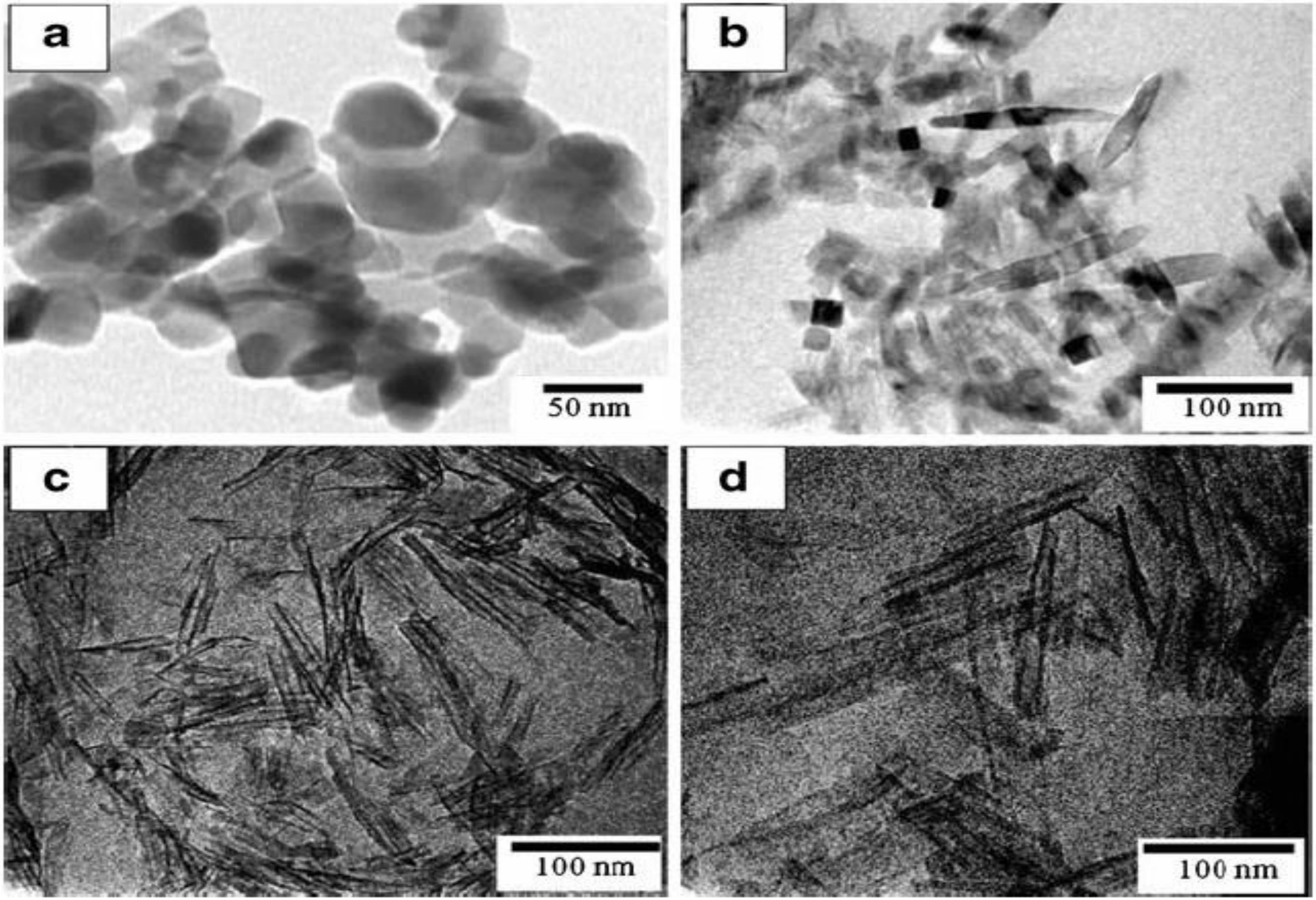
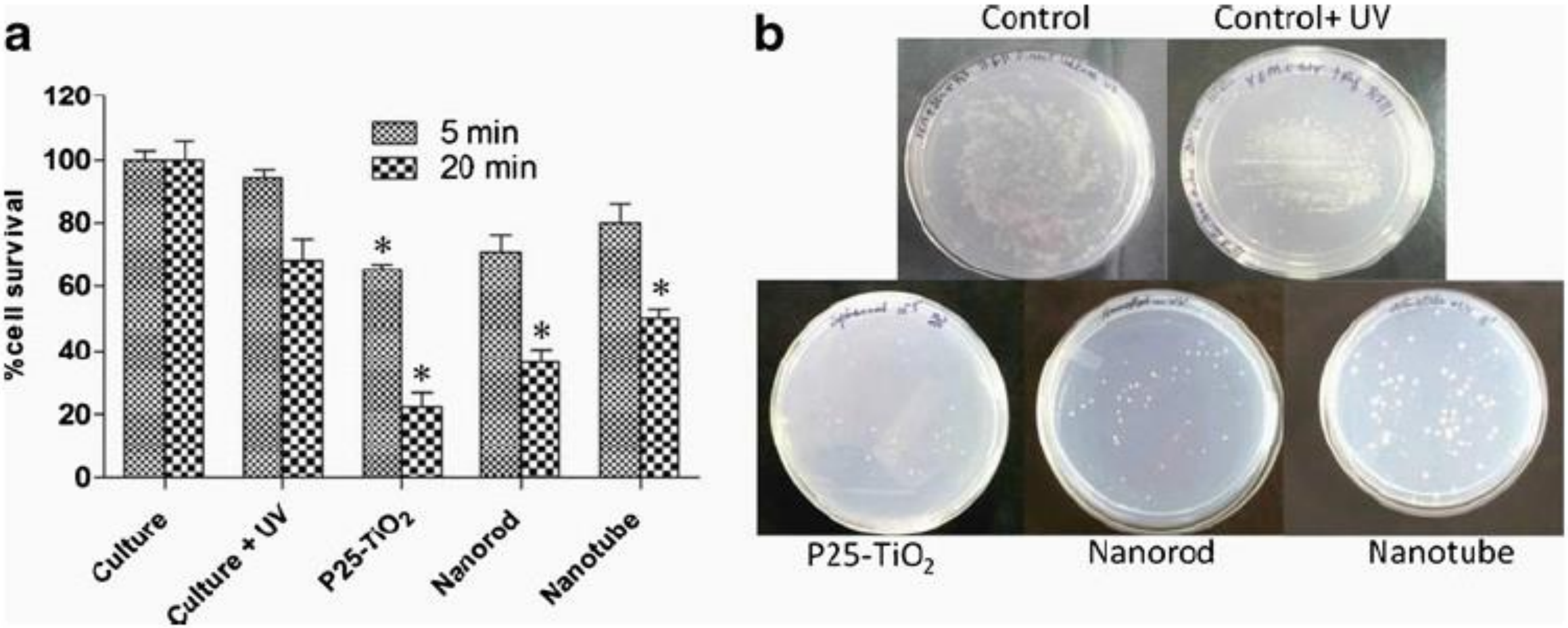


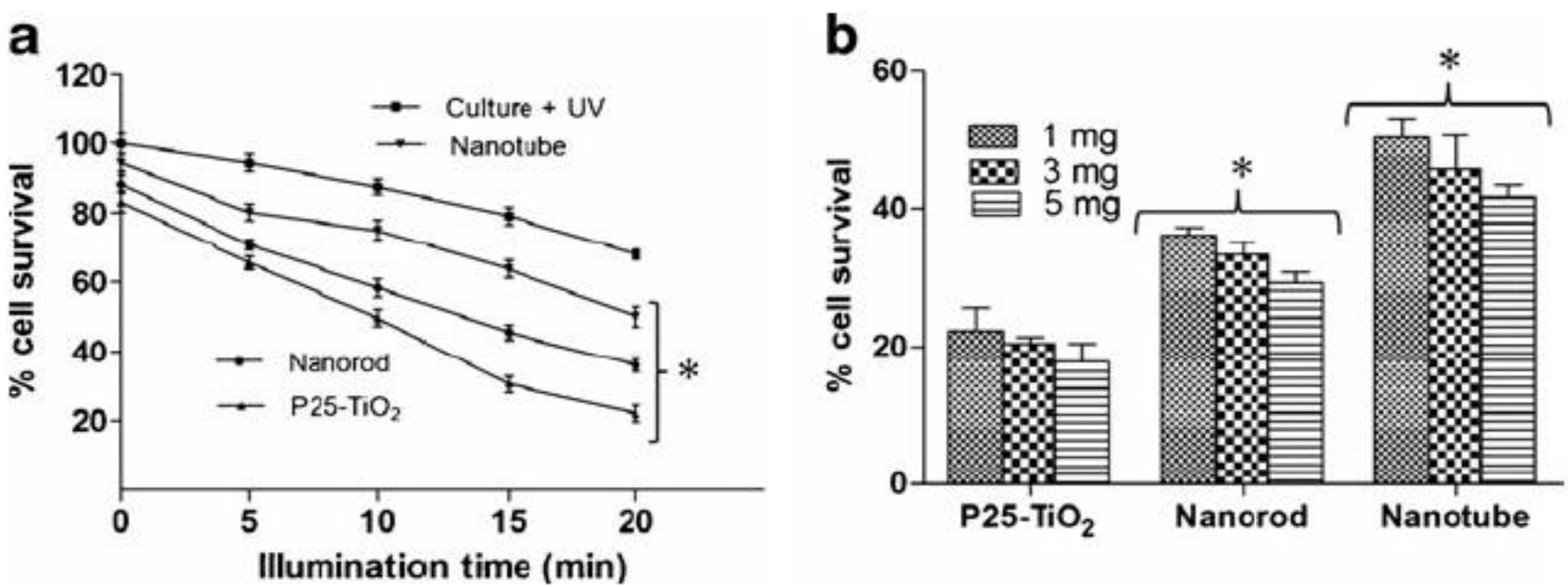
Fig. 4. Effect of the amount of Pt–TiO_2 (PD & IR) catalysts on the biocidal action of various films. *Inset*: Comparative antimicrobial activity of Pt–TiO_2 (PD & IR) catalysts powders in aqueous (5 ml) suspension after 10 min irradiation.

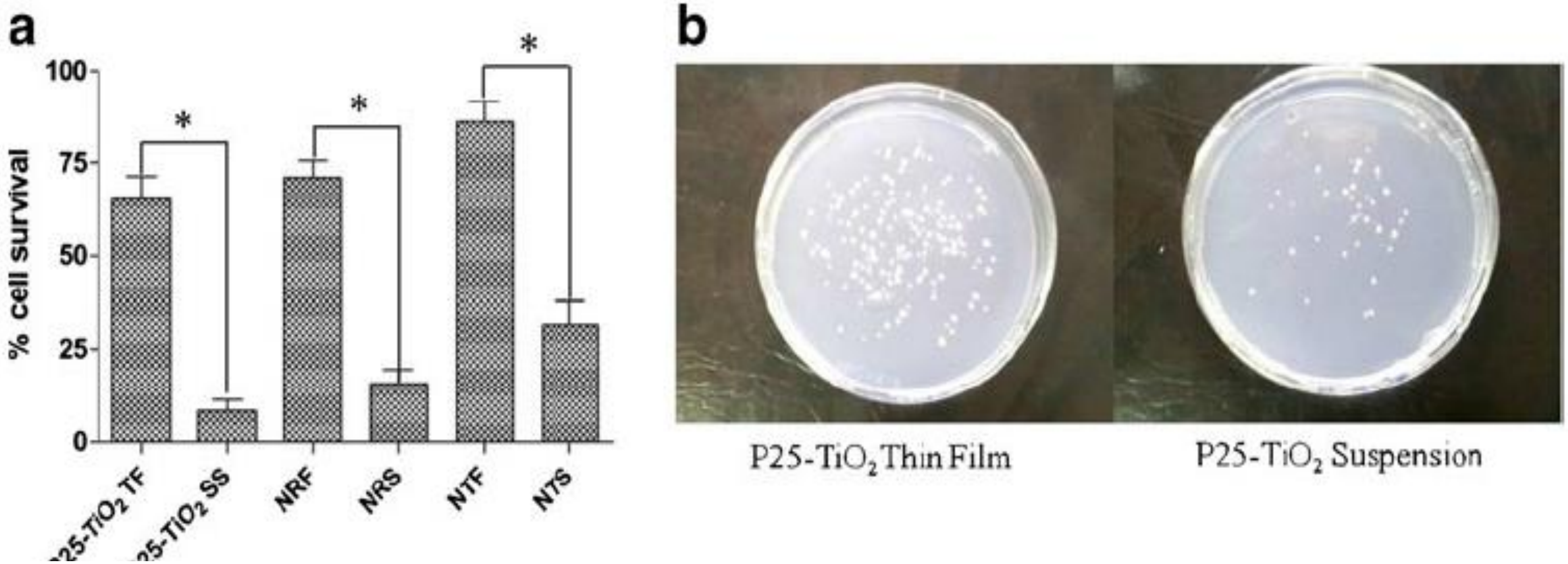


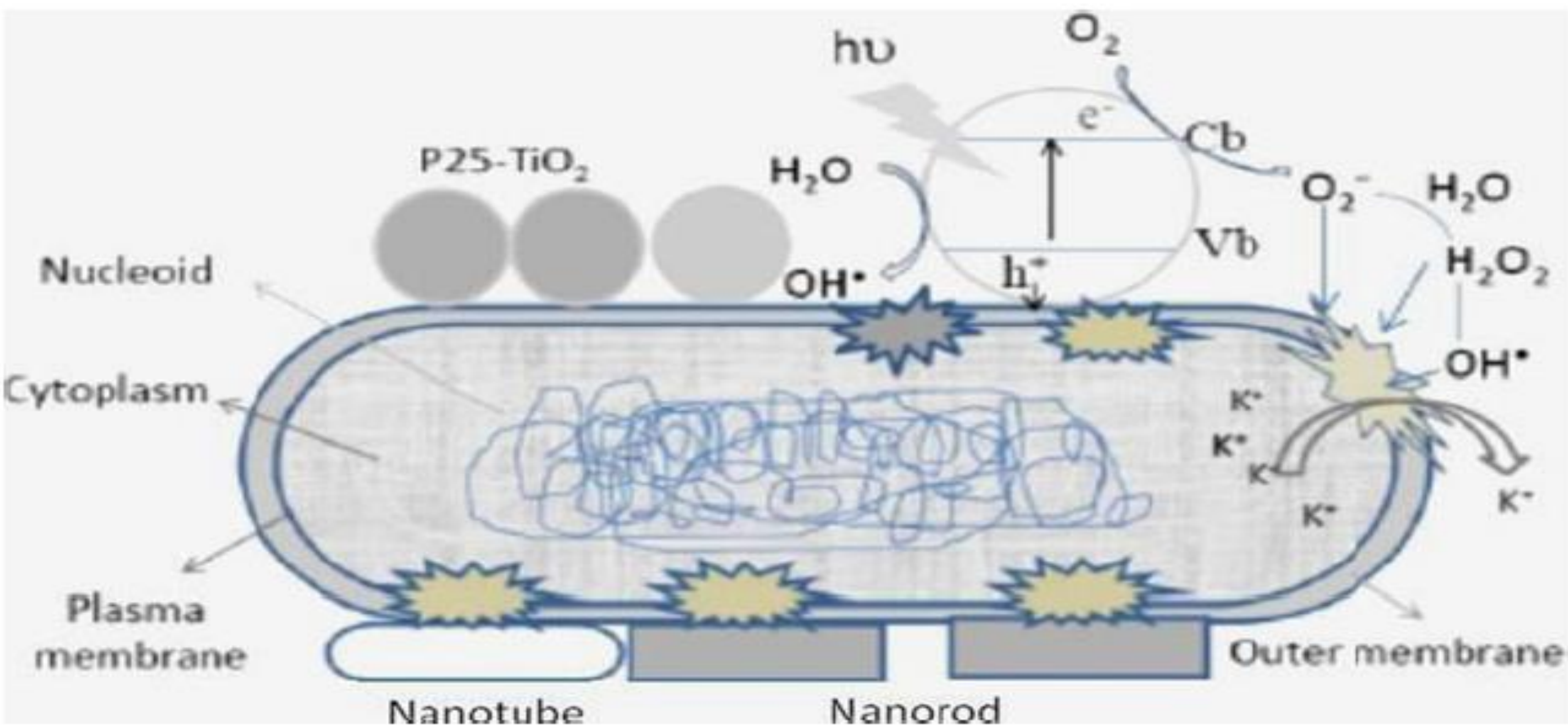
Shape-dependent bactericidal activity of TiO2 for the killing of Gram-negative bacteria Agrobacterium tumefaciens under UV torch irradiation

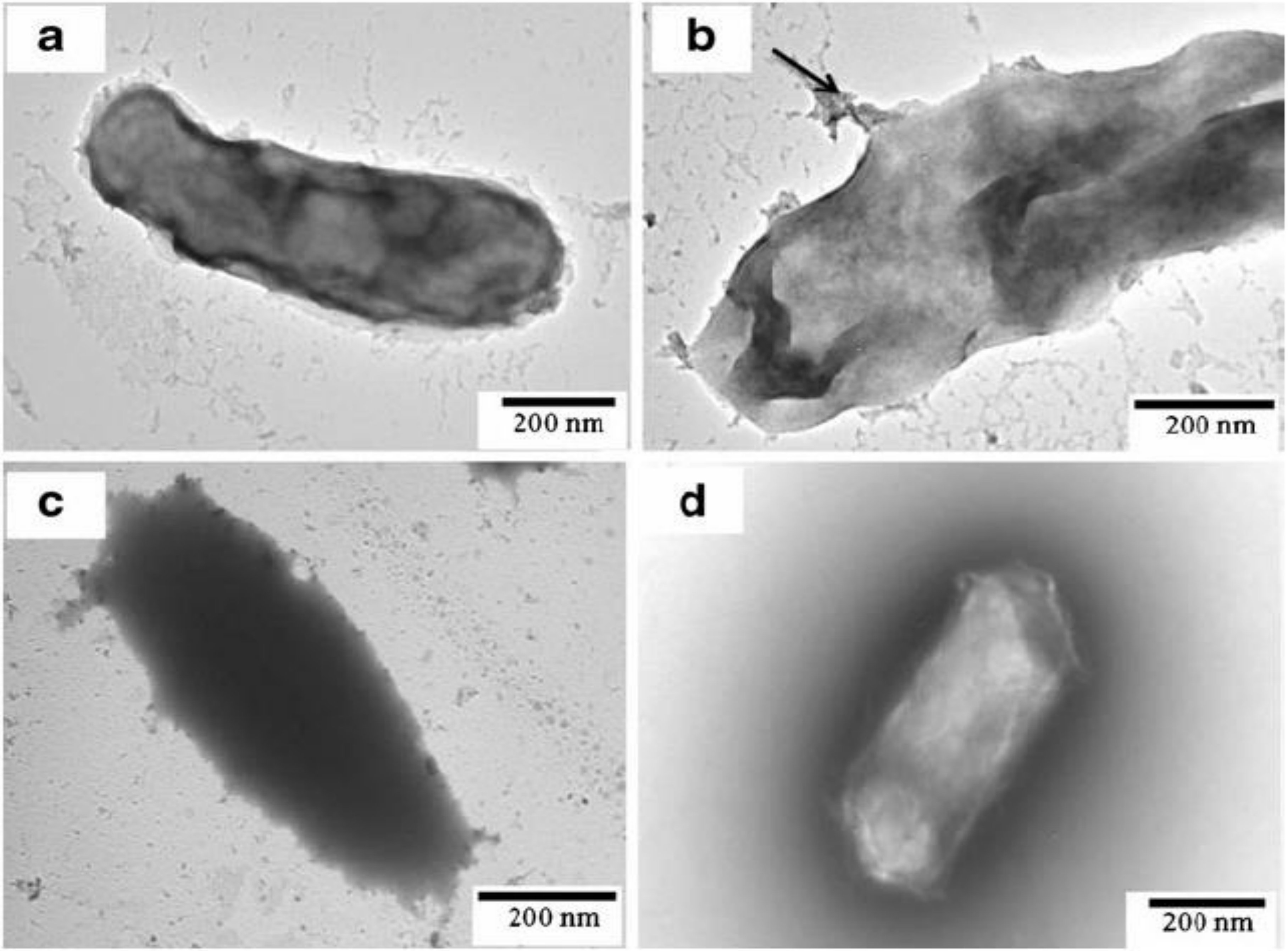



a
b
120
100
80
60
40
20
0
% cell survival
5 min
20 min
*
Culture
Culture + UV
P25-TiO2
Nanorod
Nanotube
Control
Control+ UV
P25-TiO2
Nanorod
Nanotube


a
120
100
80
60
40
20
0
5
10
15
20
% cell survival
Illumination time (min)
Culture + UV
Nanotube
Nanorod
P25-TiO2
*
b
60
40
20
0
% cell survival
1 mg
3 mg
5 mg
*
P25-TiO2
Nanorod
Nanotube


a
b
% cell survival
100
75
50
25
0
*
P25-TiO2 TF
P25-TiO2 SS
NRF
NRS
NTF
NTS
P25-TiO2 Thin Film
P25-TiO2 Suspension


hυ
O2
e-
Cb
Vb
h+
P25-TiO2
H2O
OH•
O2-
H2O
H2O2
OH•
Nucleoid
Cytoplasm
K+
Plasma membrane
Outer membrane
Nanotube
Nanorod


a
200 nm
b
200 nm
c
200 nm
d
200 nm

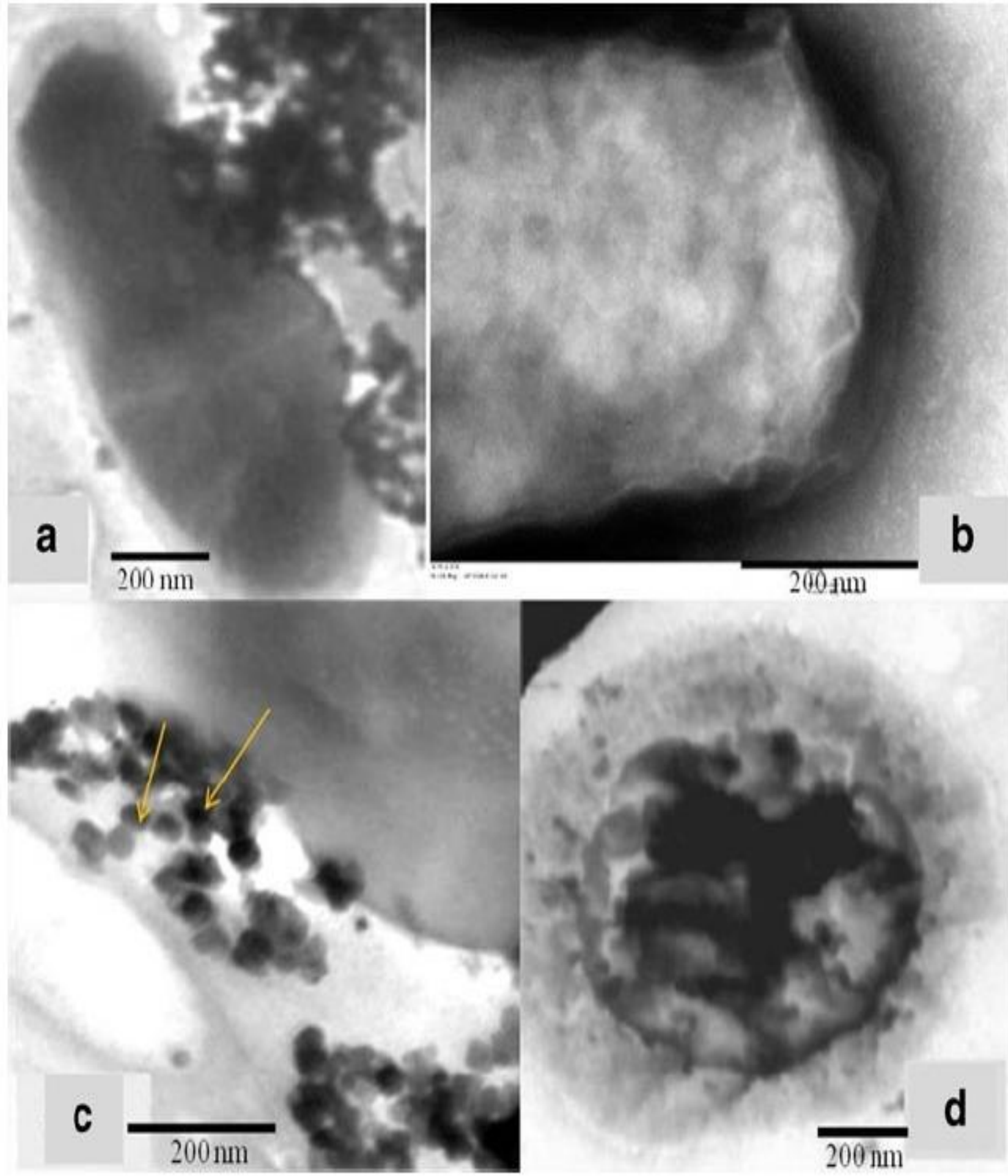


Fig. 6 TEM surface morphology of damaged *A. tumefaciens* cells (*scale bar* 200 nm) obtained after 30 min UV irradiation of P25–TiO_2 and 3.6×10^8 CFU mL^{-1} of bacterial suspension; **a** bacterial surface is etched at two different locations by attached TiO_2 particles, **b** bacterial surface is becoming thinner due to gradual dissolution of cell constituents, **c** an enlarged view of the etched cell surface by irradiated TiO_2, **d** decomposed and ruptured bacterial lump

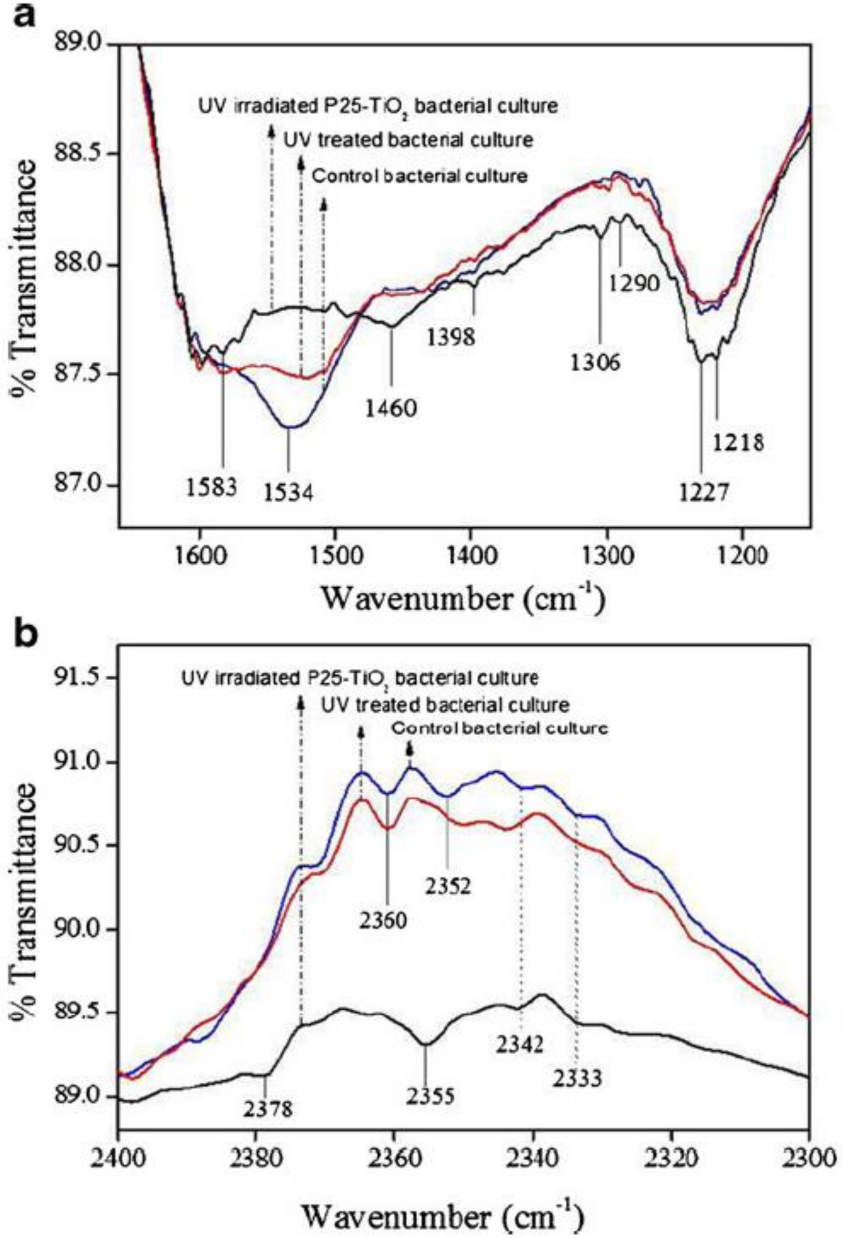


Fig. 7 FT-IR spectral bands of control cell culture, UV illuminated cells and UV irradiated P25–TiO_2 of *A. tumefaciens* suspension in the range of **a** 1,600–1,200 cm^{-1} and **b** 2,400–2,300 cm^{-1}

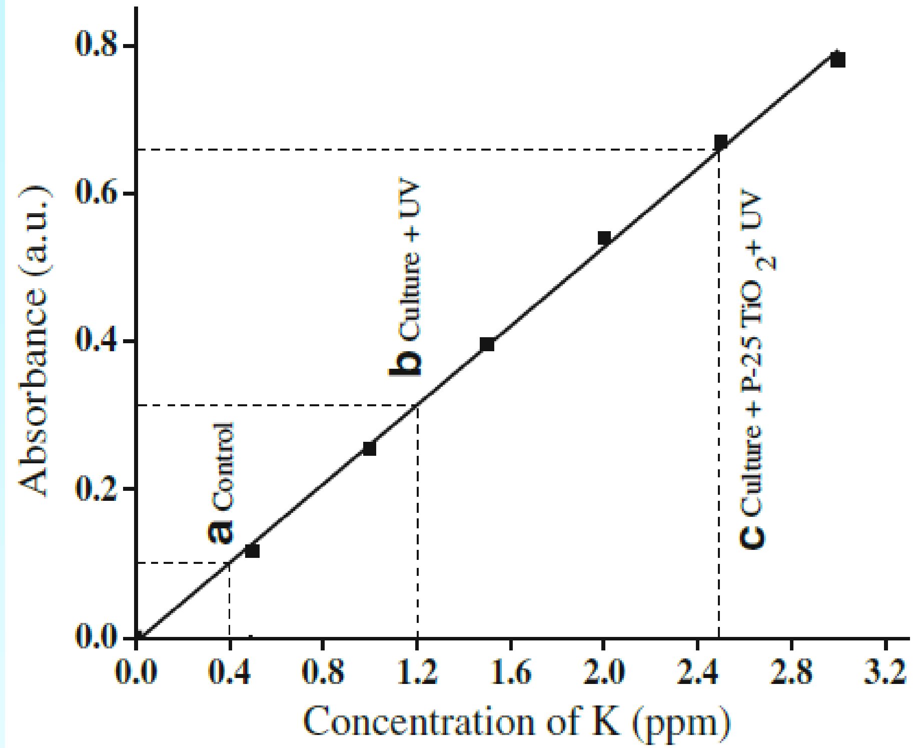
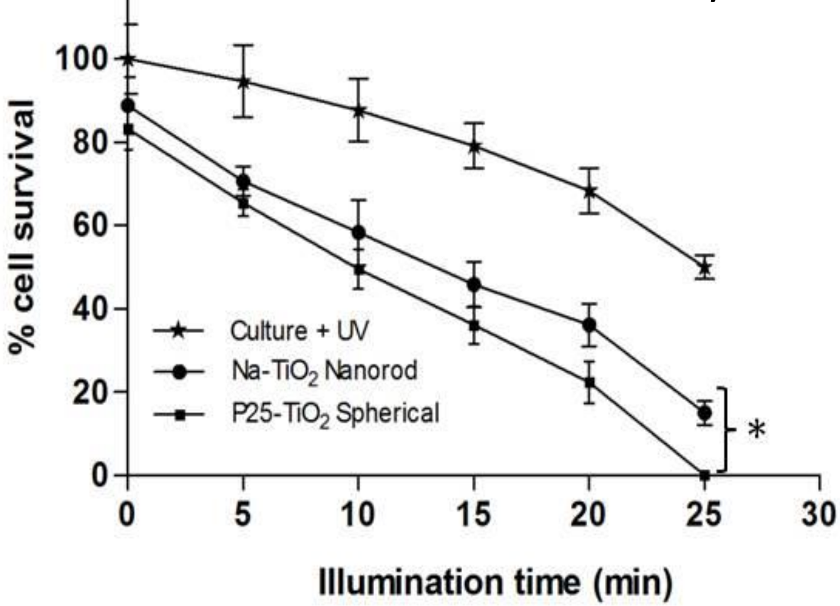
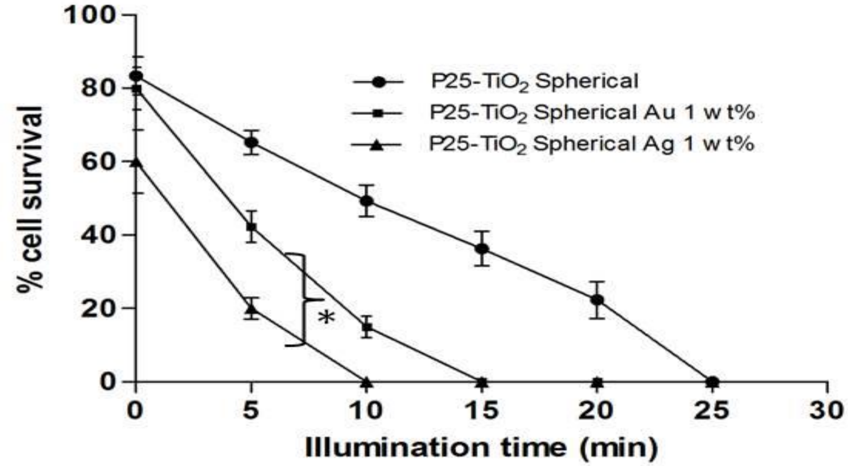


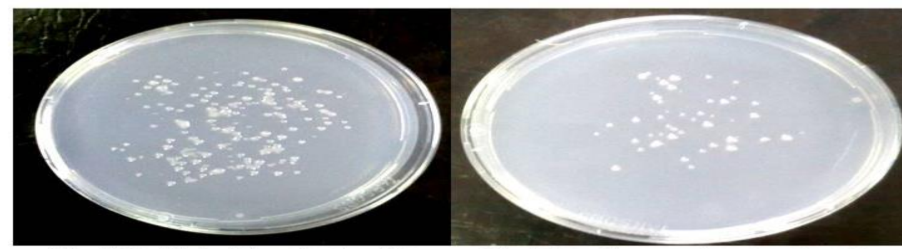
Fig. 8 Leakage of K^+ ion from *A. tumefaciens* under different conditions; **a** control, i.e., P25–TiO_2 treated with bacterial suspension placed in the dark; **b** UV irradiation for 5 min without catalyst; and **c** P25–TiO_2 and bacterial suspension irradiated with UV for 5 min

Effect of metal –TiO2 catalysts

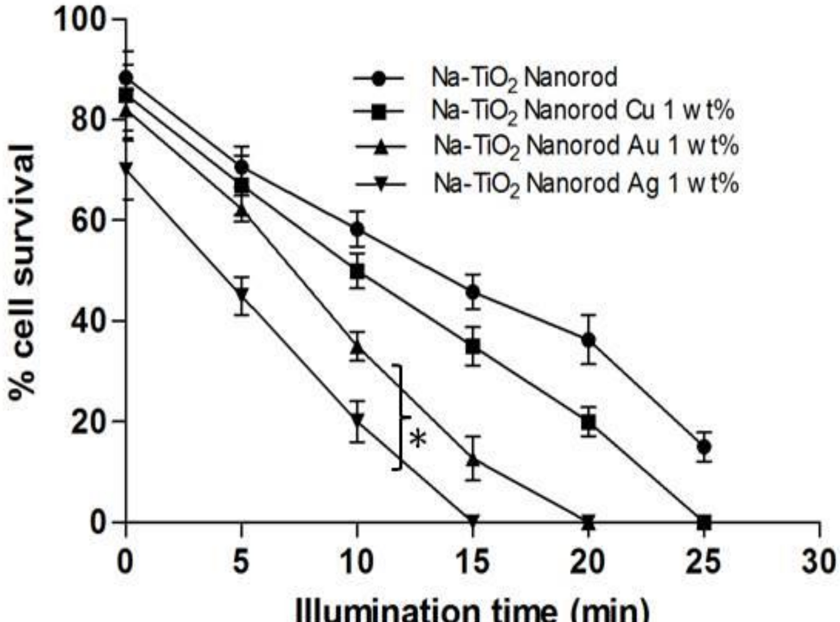




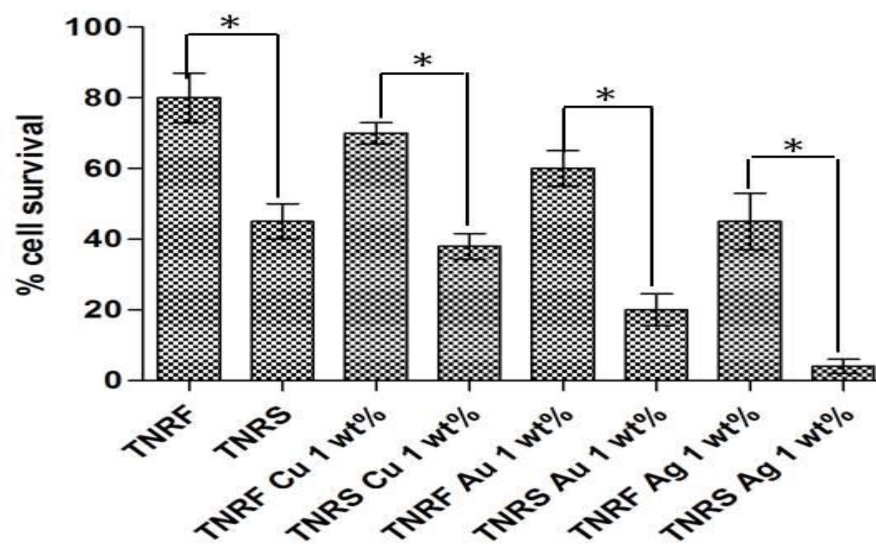
B

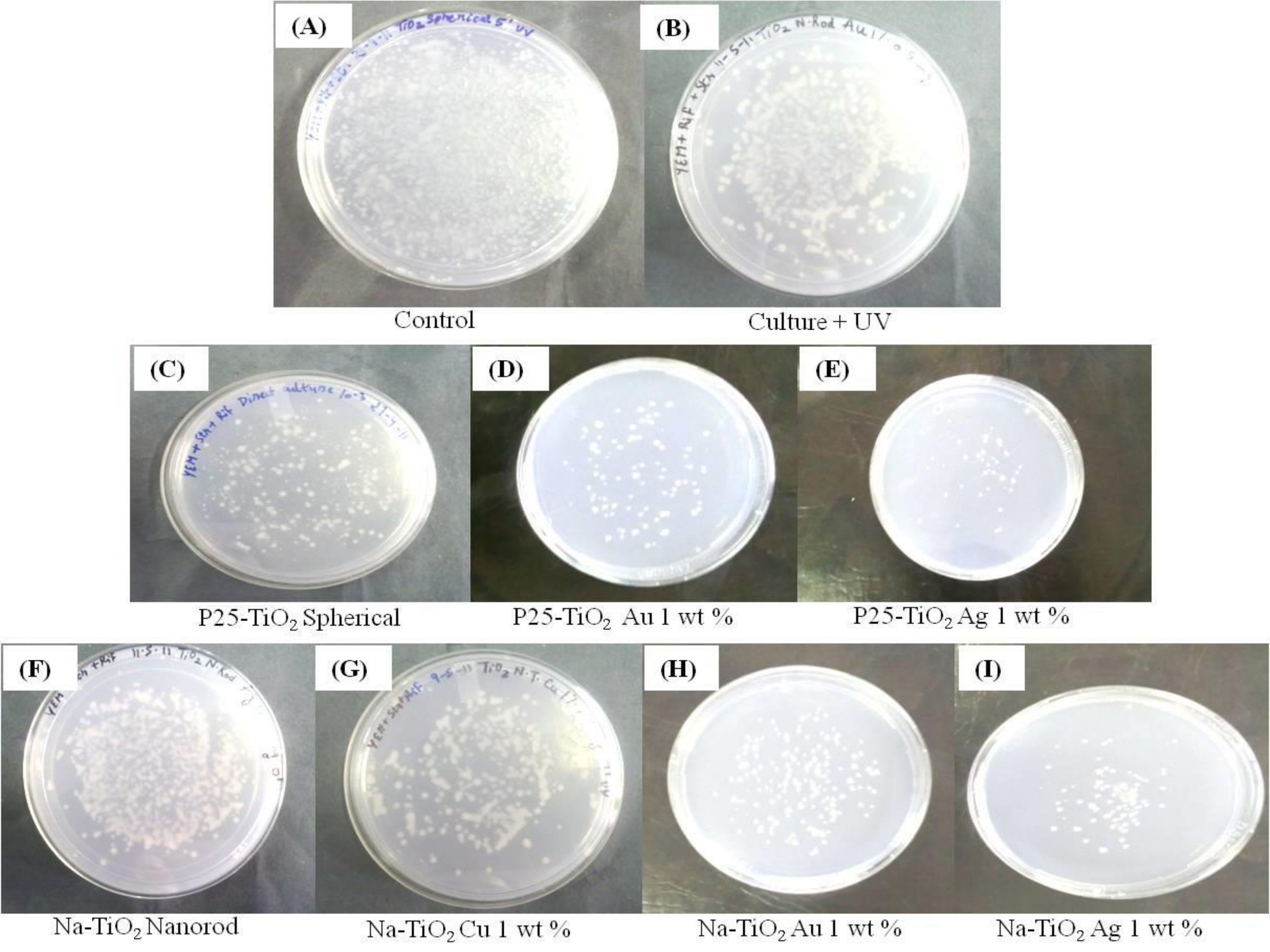


Na-TiO2 Thin film Au 1 wt% Na-TiO2 Suspension Au 1 wt%

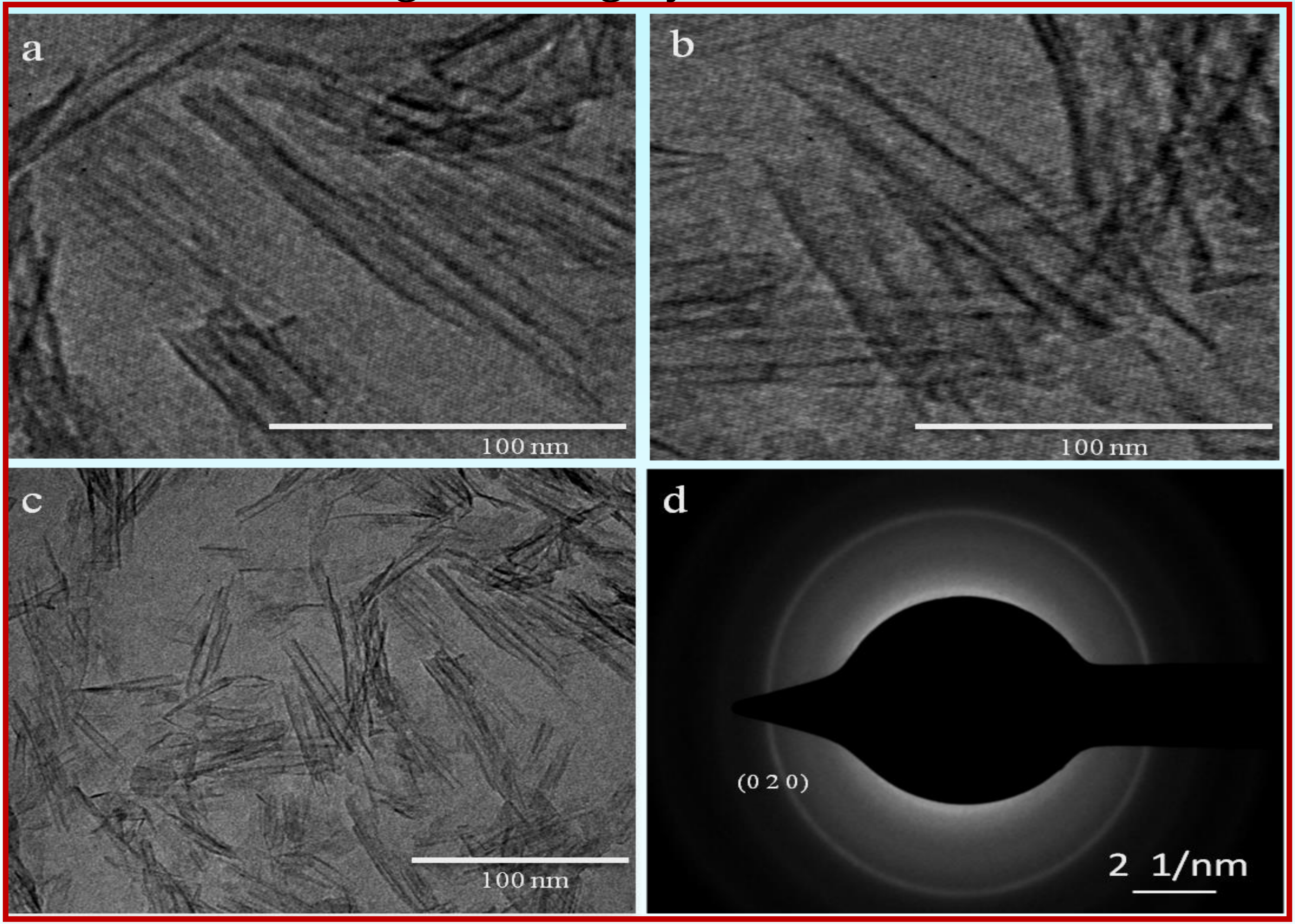


A



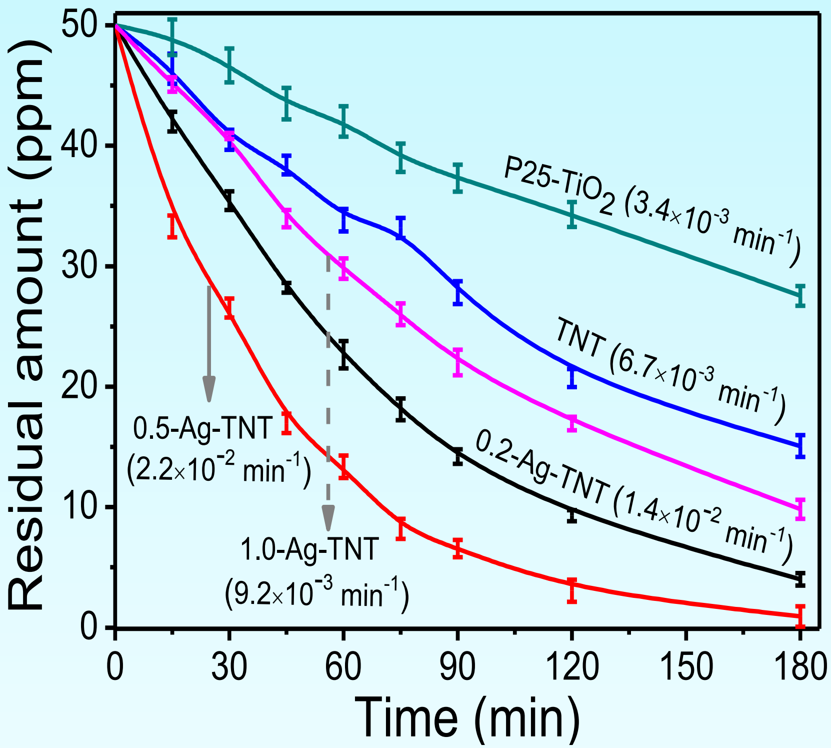

(A)
Control
(B)
Culture + UV
(C)
P25-TiO_2 Spherical
(D)
P25-TiO_2 Au 1 wt %
(E)
P25-TiO_2 Ag 1 wt %
(F)
Na-TiO_2 Nanorod
(G)
Na-TiO_2 Cu 1 wt %
(H)
Na-TiO_2 Au 1 wt %
(I)
Na-TiO_2 Ag 1 wt %

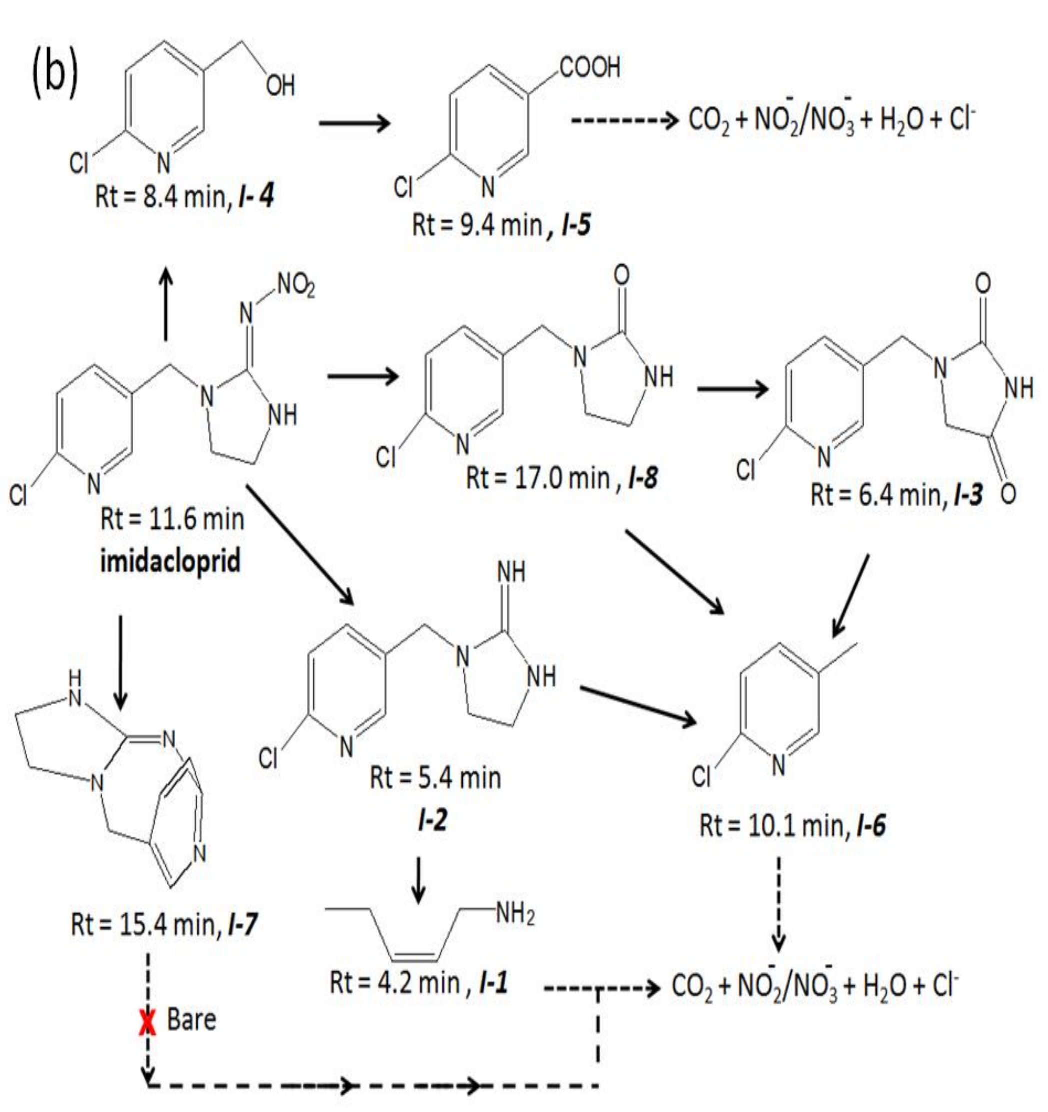
TEM images of lenghty Titanate Nnotubes



Photomineralization and mechanistic study of Imidacloprid insecticide by Ag deposited sodium titanate nanotubes

Photocatalytic activity

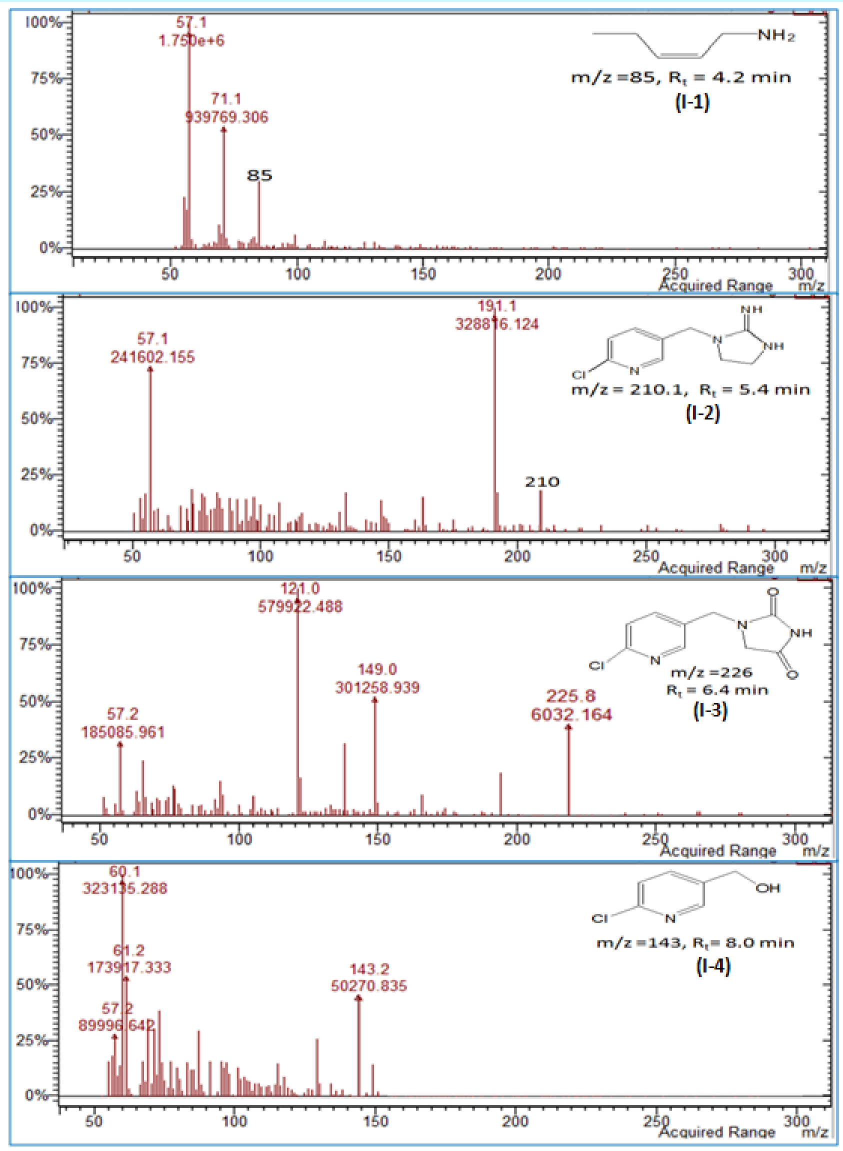


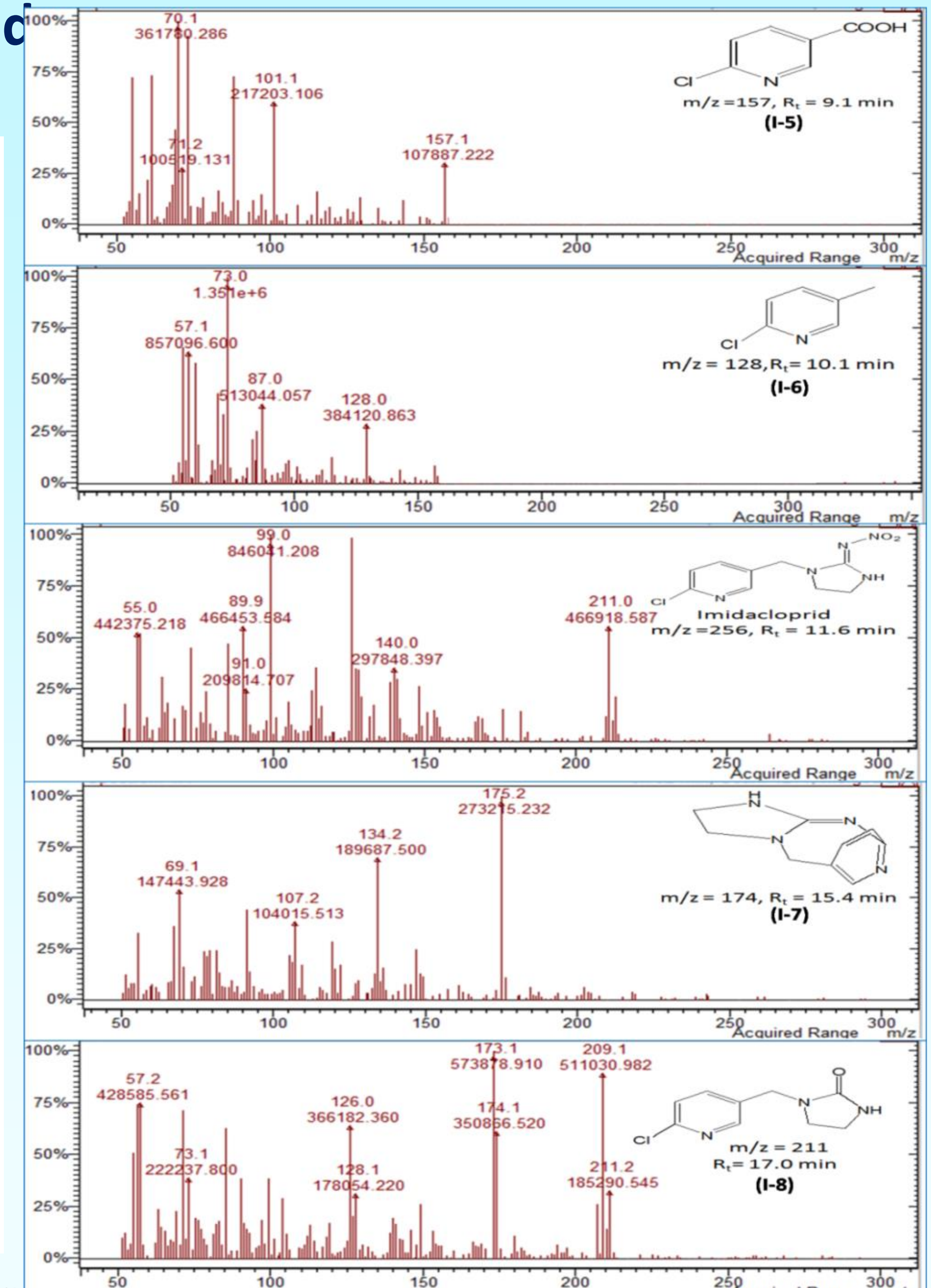


✓**Ag loading increase the photocatalytic activity.**

✓**Increase in amount of Ag-loading(> 0.5 wt%) decreases the photocatalytic activity.**

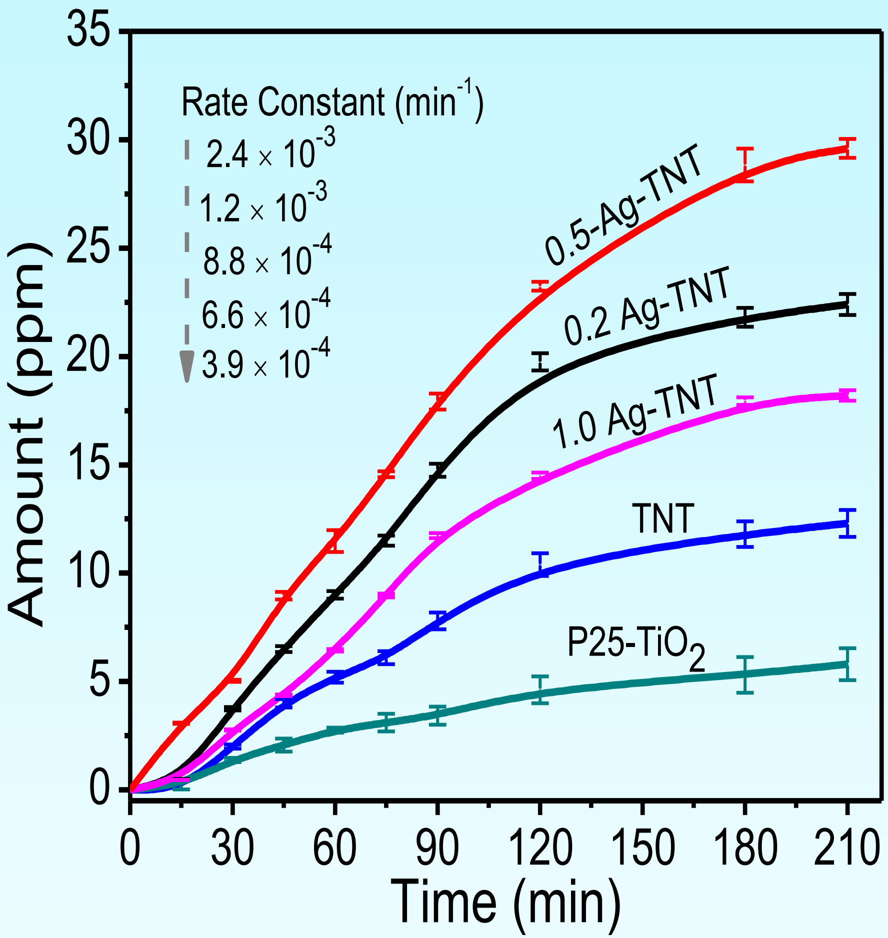
MS-Chromatographs for identified intermediates



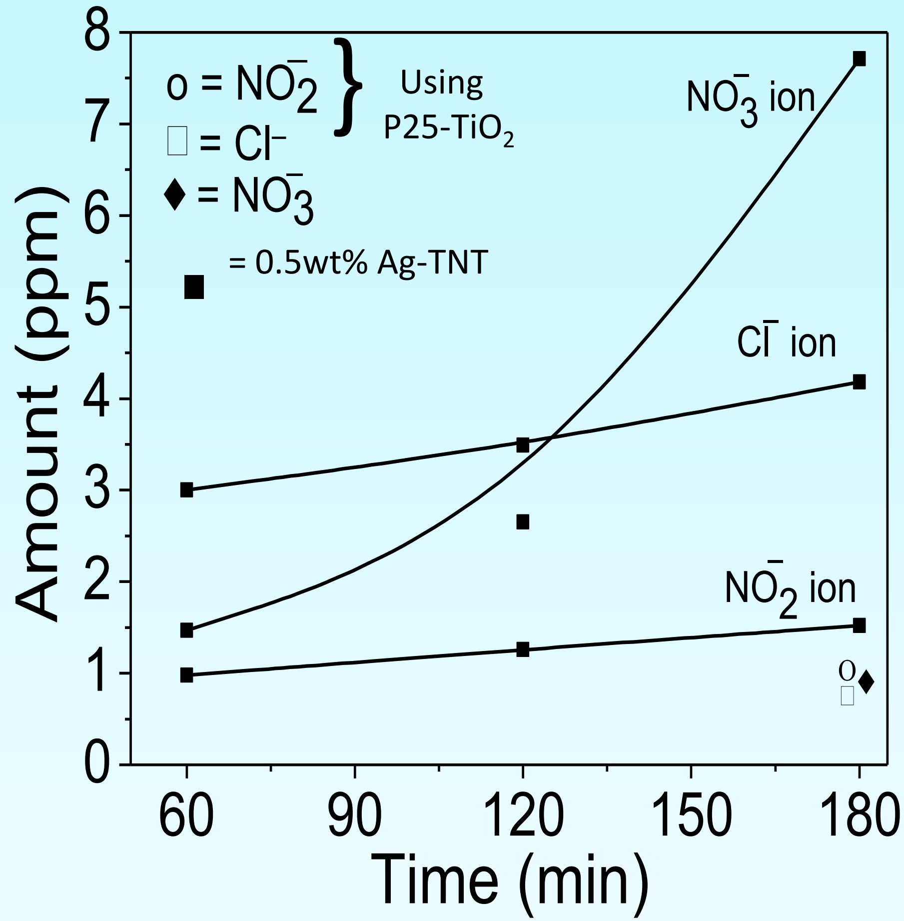


Y-axis = intensity (%)

CO_2 Formation



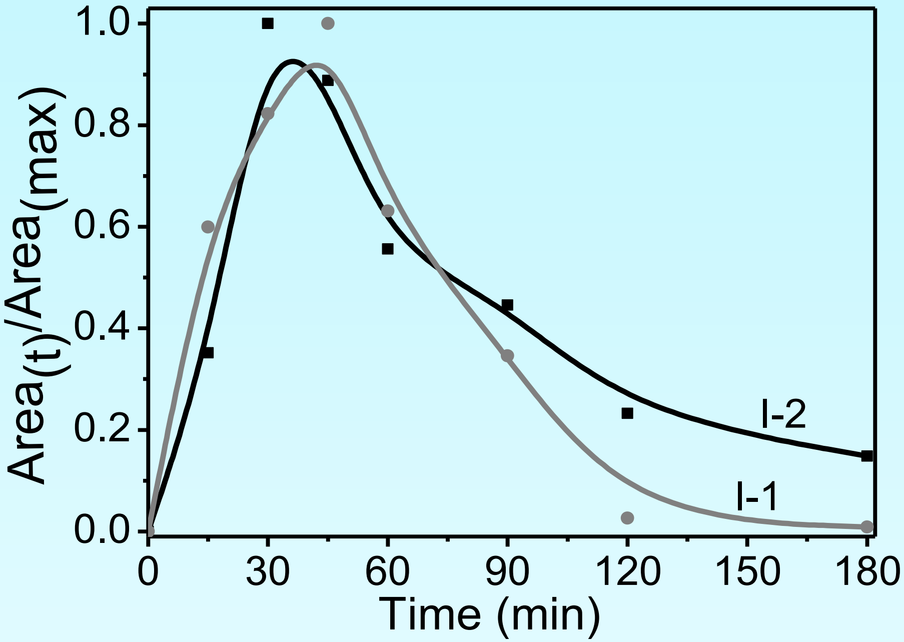
Ions Formation

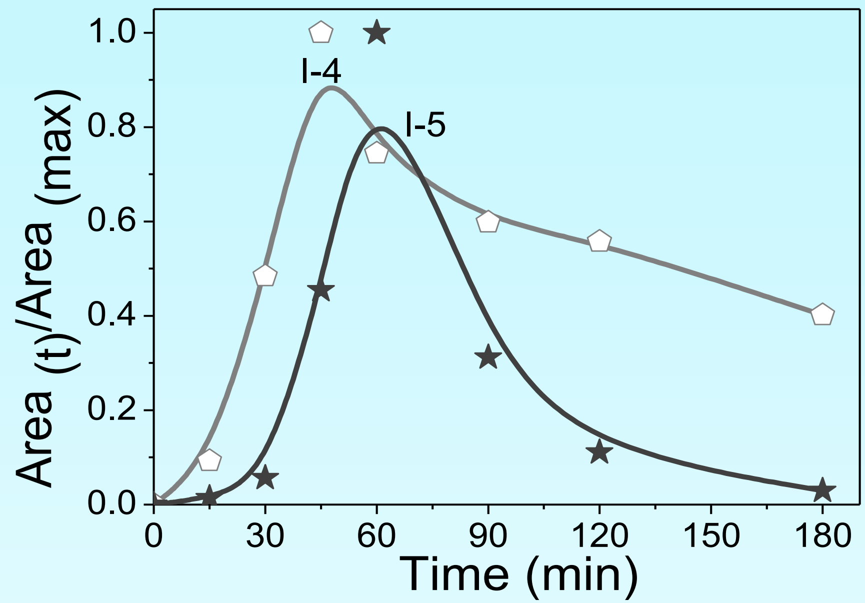


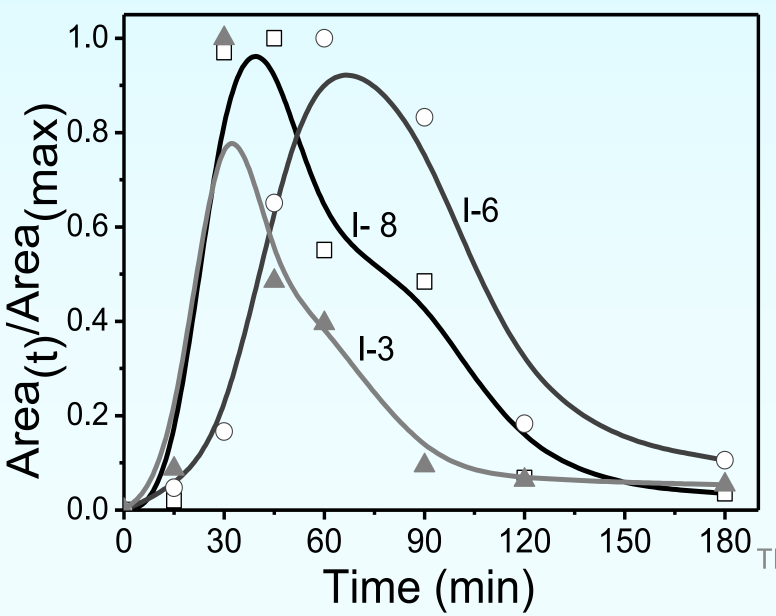
✓ **Formation of ions confirms mineralization**

✓ **0.5-Ag-TNT showed maximum mineralization = 34 %**

Time course study for intermediate formation/degradation during photooxidation of imidacloprid and mass balancing







Stoichiometric chemical equations:

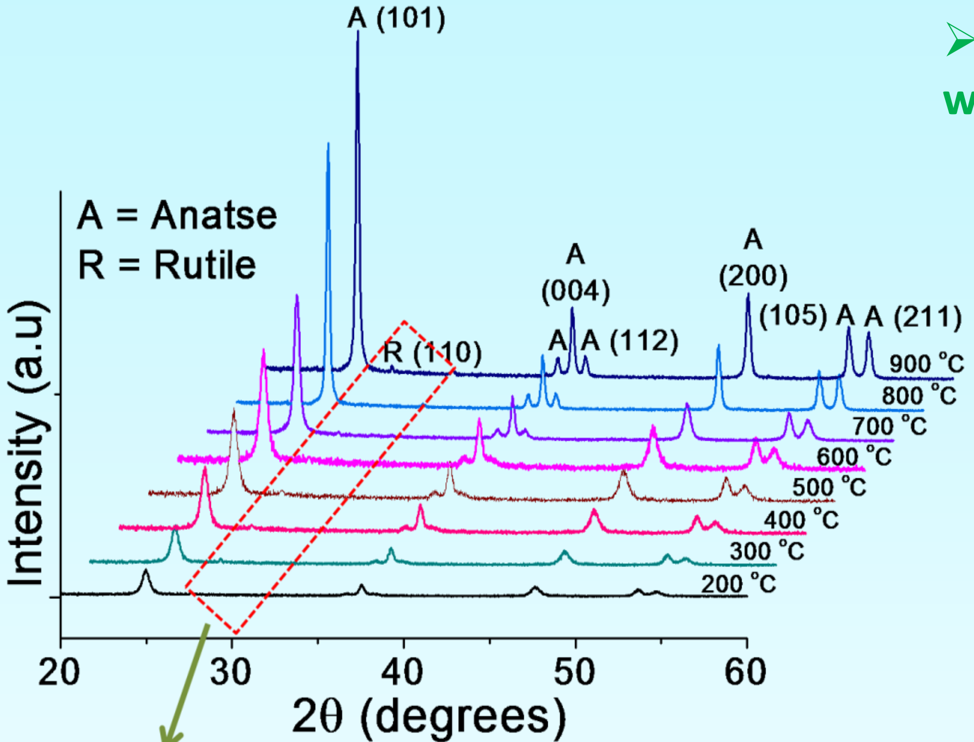
$$C_9H_{10}N_5O_2Cl + 5/2\ O_2 \xrightarrow{(A)} 2.88\ CO_2 + 0.04\ NO_2^- + 0.62\ NO_3^- + 0.6\ Cl^- + \text{intermediates}$$

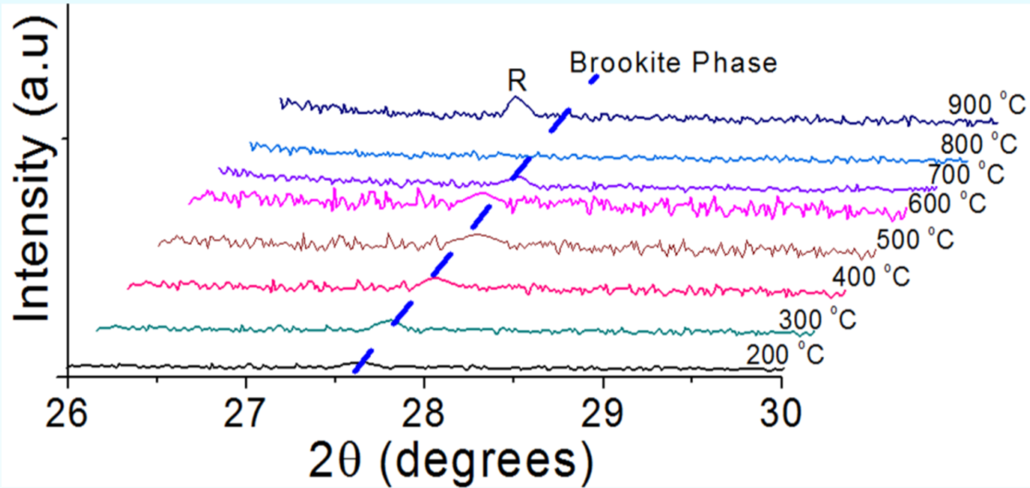
(A) = hv, 0.5wt% Ag-TNT, 180 min

Theoretical

$$C_9H_{10}N_5O_2Cl + 17\ O_2 \longrightarrow 9\ CO_2 + 5\ NO_3^- + Cl^- + 4\ H^+ + 3H_2O$$

High temperature synthesis of anatase TiO_2 and its improved photocatalytic activity for degradation of Methyl Parathion

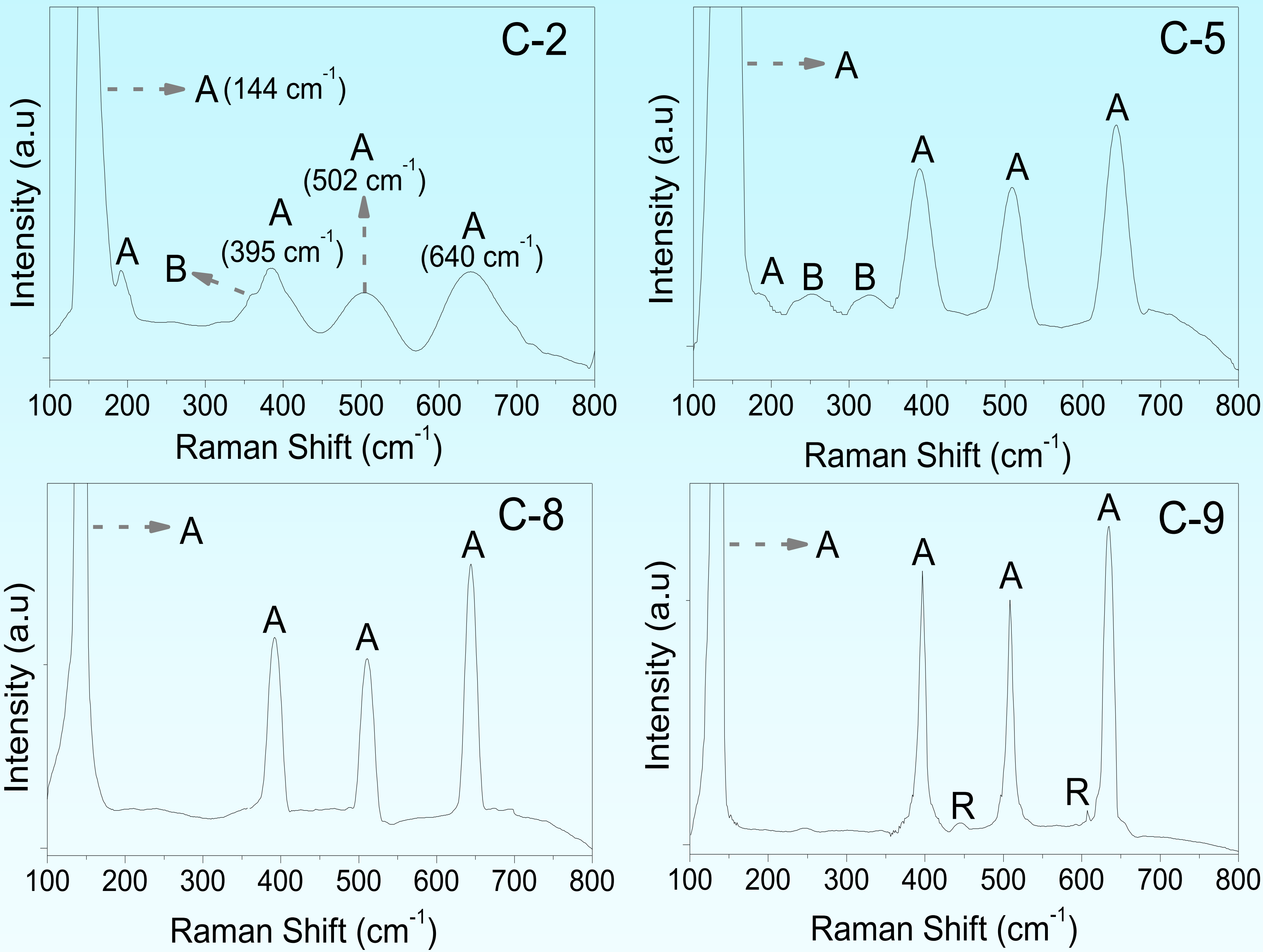




- Gradual Improvement in crystallinity with rise of calcination temperature.
- Initiation of anatase-to-rutile transformation at > 800 °C

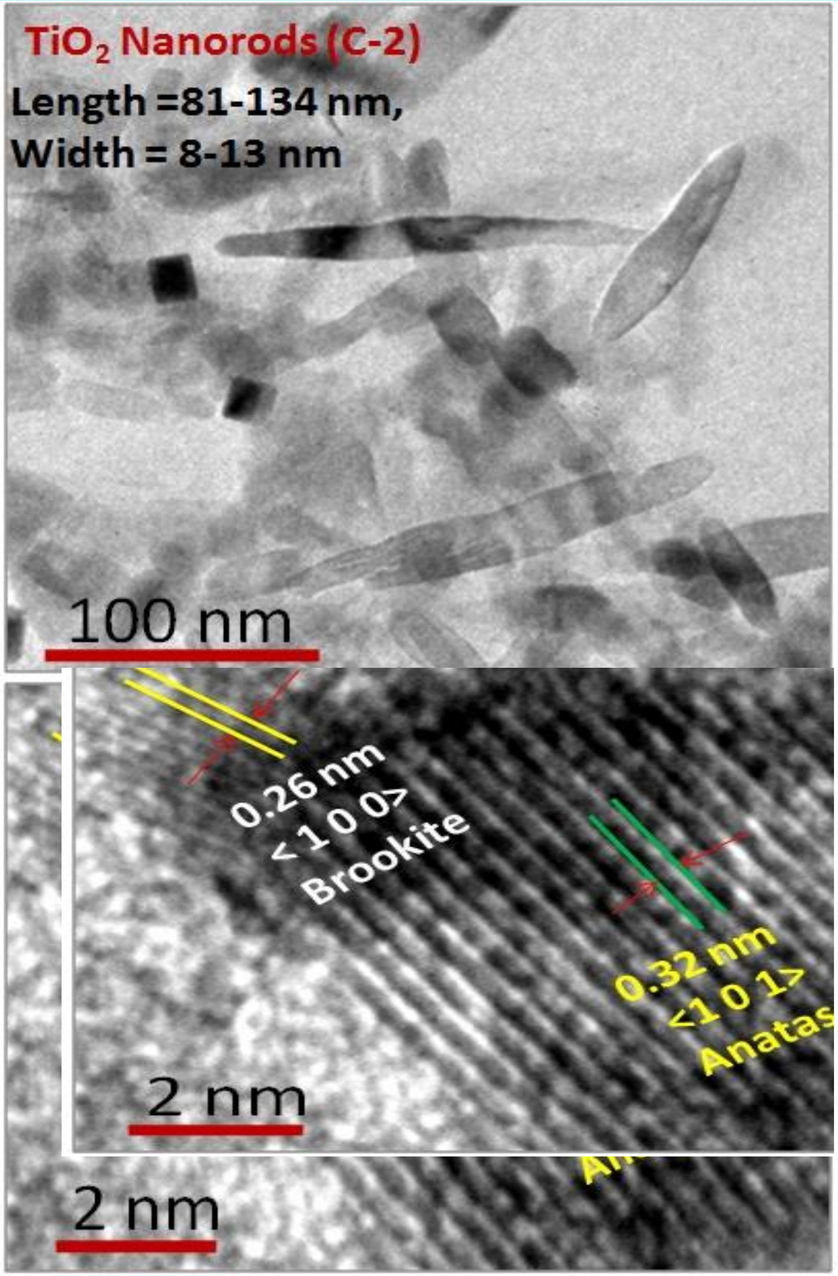
Calcination Temp. (°C)	*Anatase Crystallite Size (nm)	S_{BET} (m^2g^{-1})
200	16	79
300	20	68
400	23	61
500	28	57
600	31	49
700	34	40
800	38	35
900	40	31

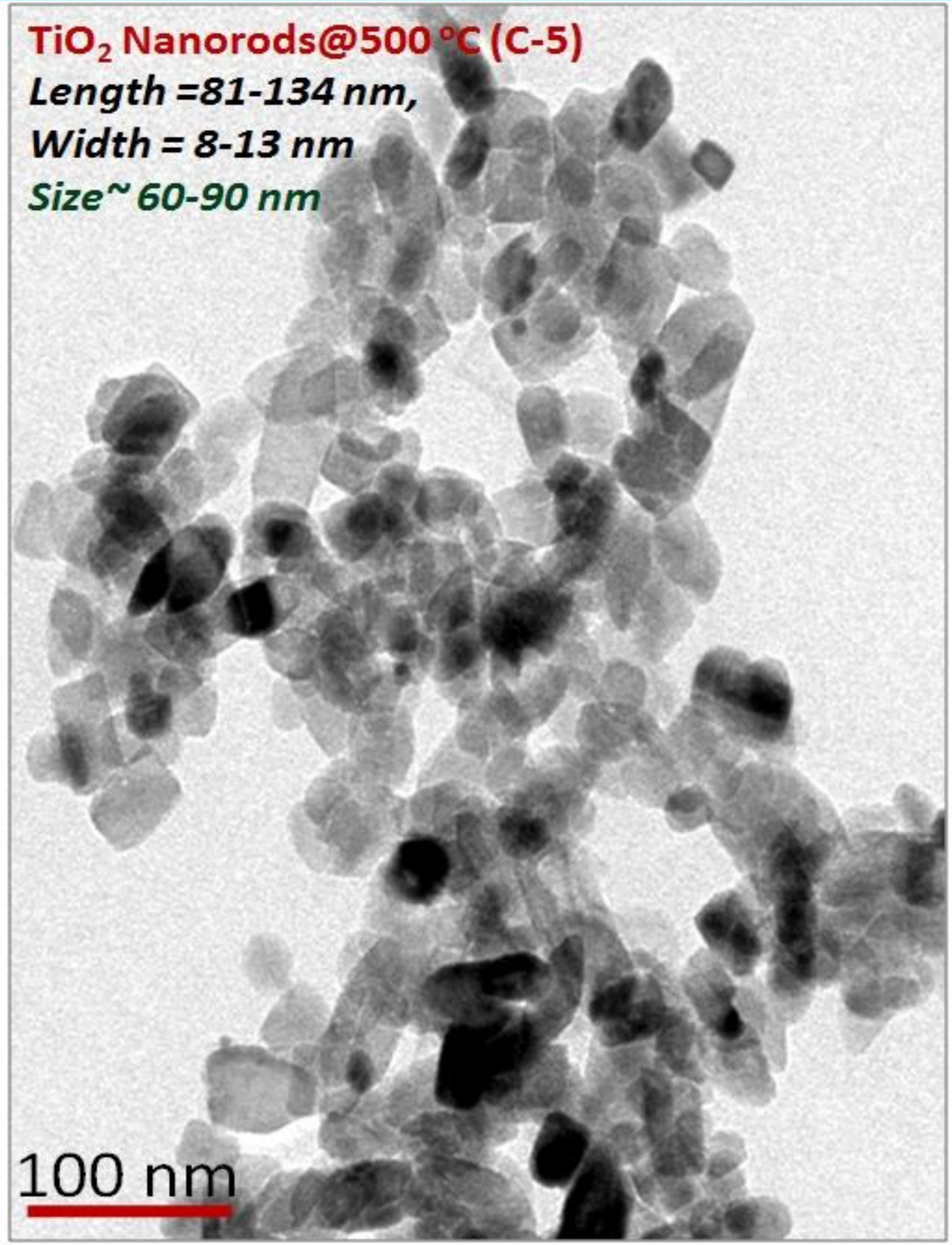
*Calculated using Scherrer Equation $d = 0.9\lambda/(\beta \cos \theta)$, d= crystallite size, $\lambda = 1.5$ Å, β =full width at half maxima



C-2
A (144 cm-1)
A
(502 cm-1)
A
(395 cm-1)
A
(640 cm-1)
A
B
Intensity (a.u)
Raman Shift (cm-1)
C-5
A
A
A
A
A
B
B
Intensity (a.u)
Raman Shift (cm-1)
C-8
A
A
A
A
Intensity (a.u)
Raman Shift (cm-1)
C-9
A
A
A
A
R
R
Intensity (a.u)
Raman Shift (cm-1)

HR-TEM Images





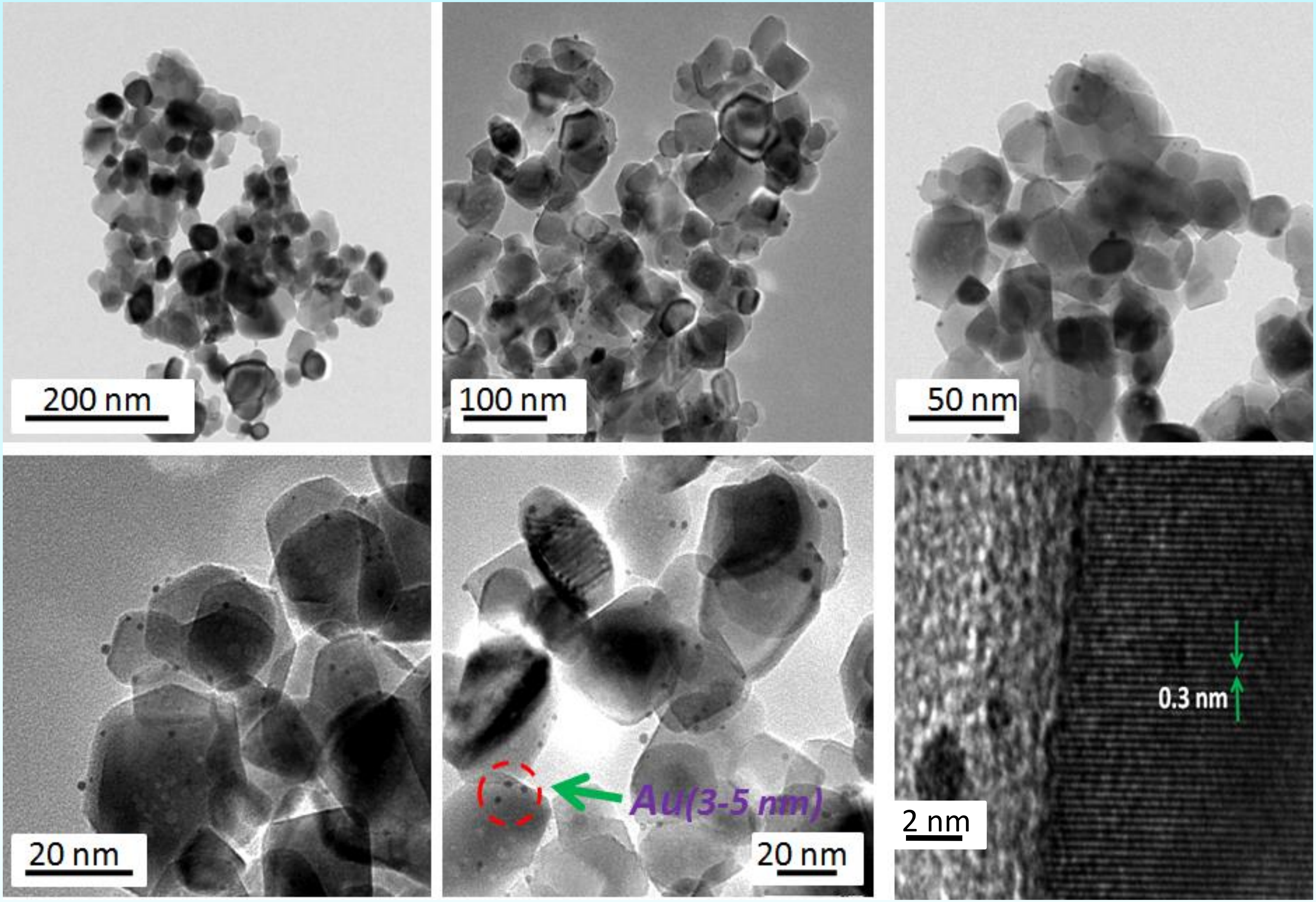
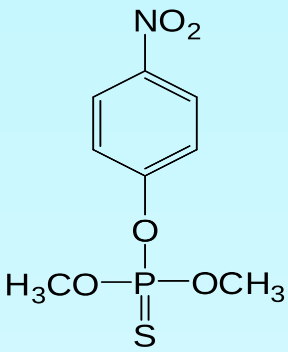


Fig. (a-e)HR-TEM Images for 1 wt% Au- TiO_2 nanorods calcined at 800 ^oC and (f) corresponding lattice fringe width

Photocatalytic activity

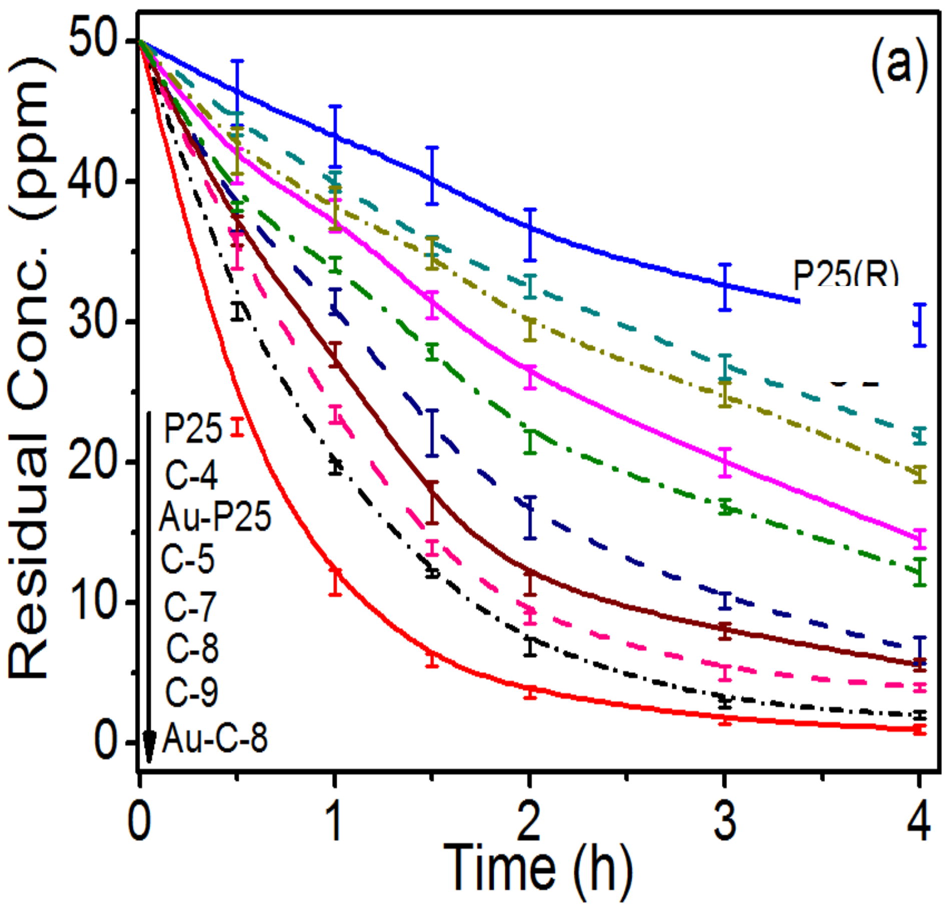


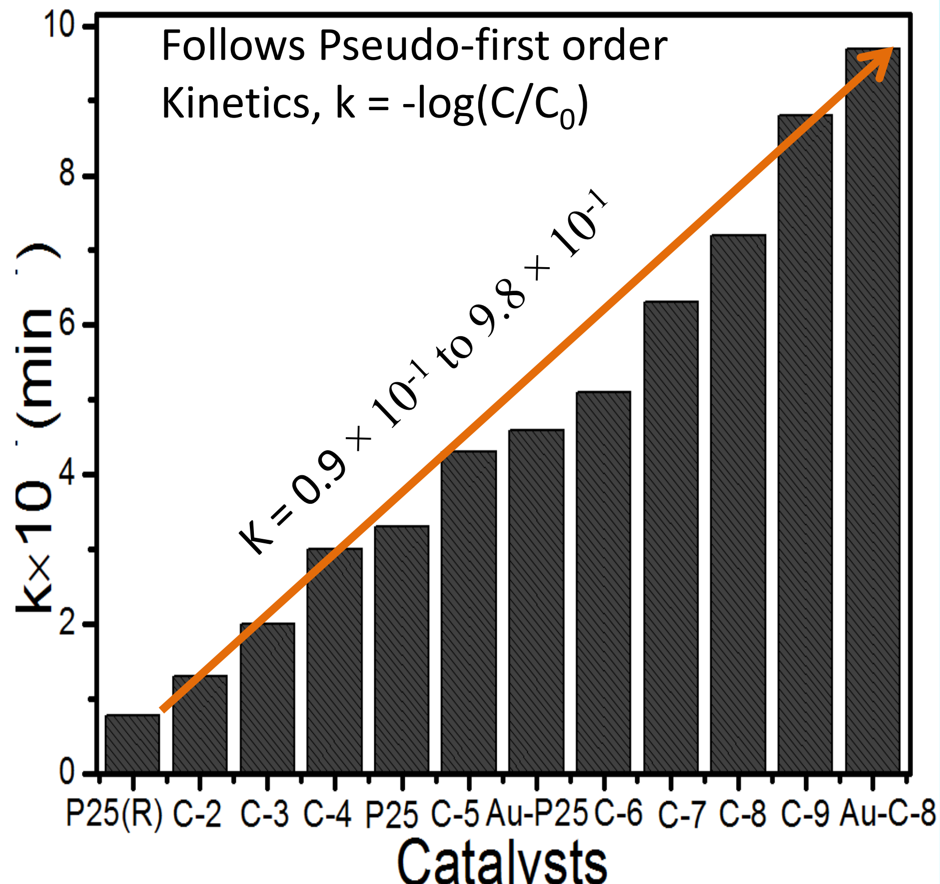
Methyl Parathion

$T_{1/2}$ = ~179 days

- Restricted, since 1999 as per EPA

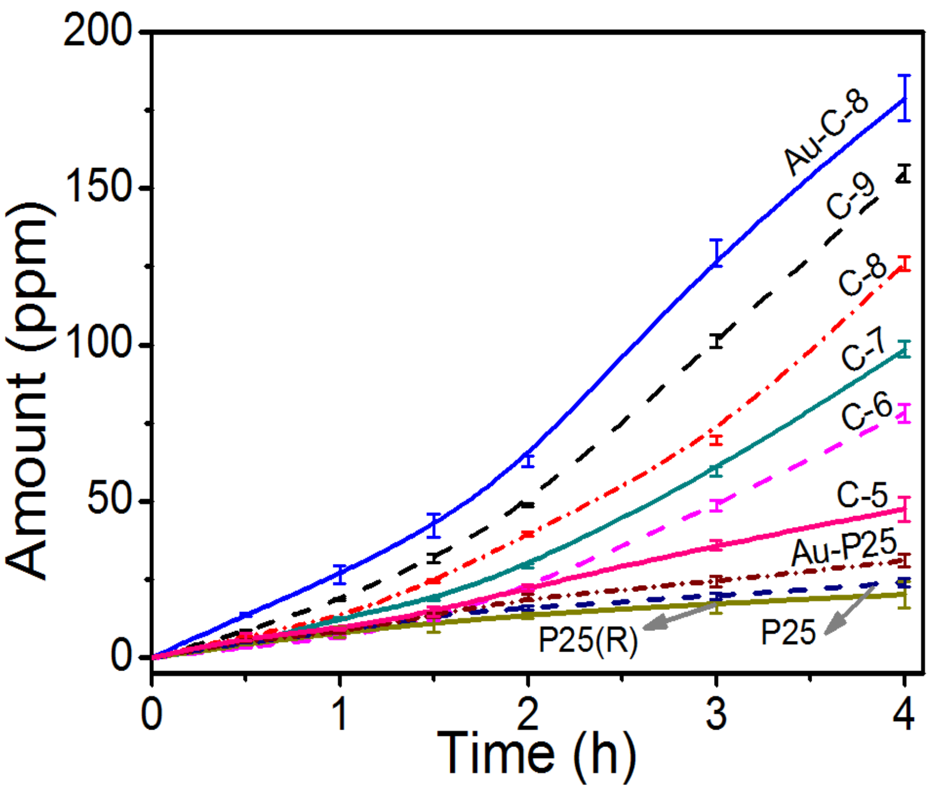
❖ **Potential Health Affects : Headache, loss of vision and conscious, severe depressions, sleep walking, and death**

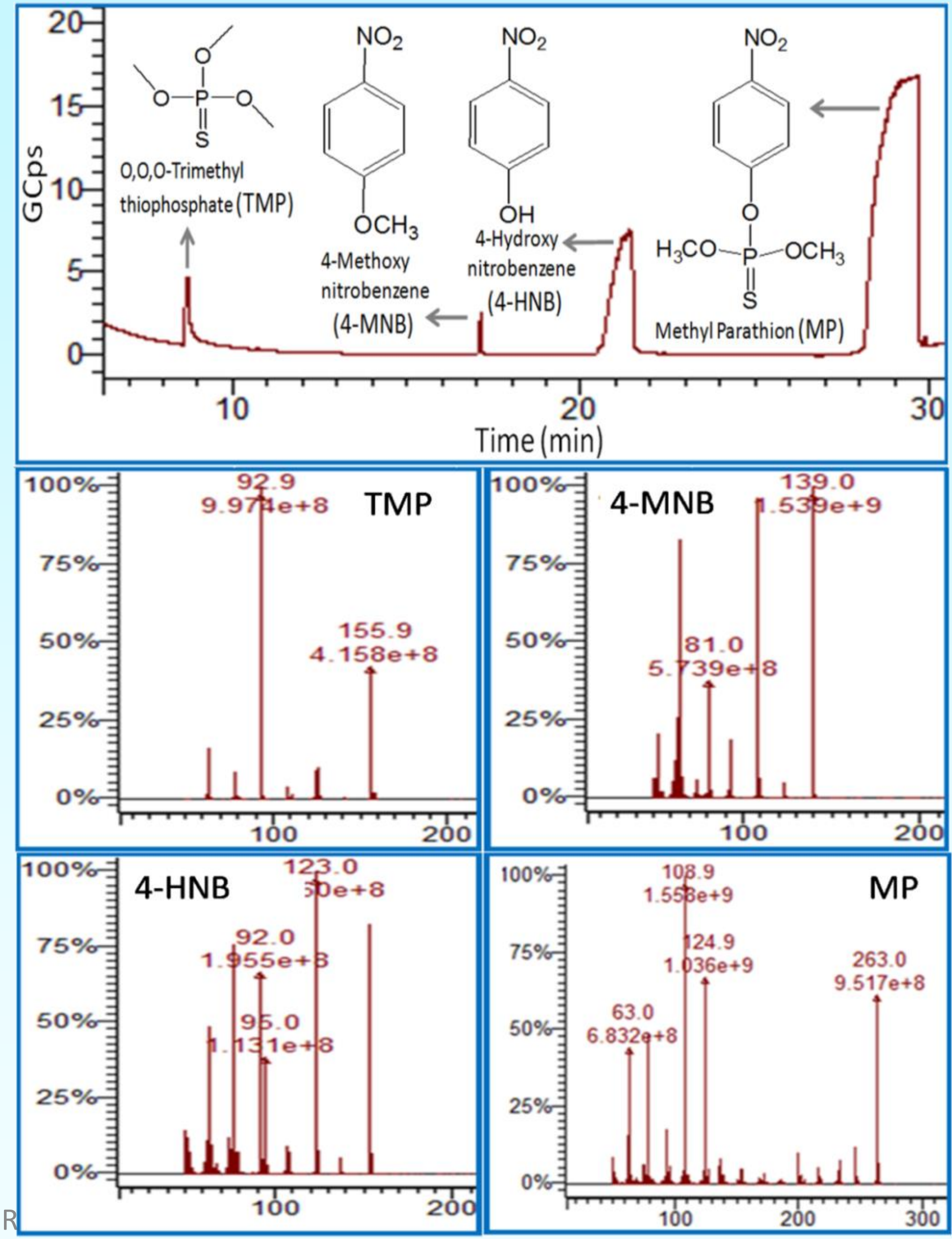




Estimation for CO_2 formation

Intermediate's Identification





Conclusions:

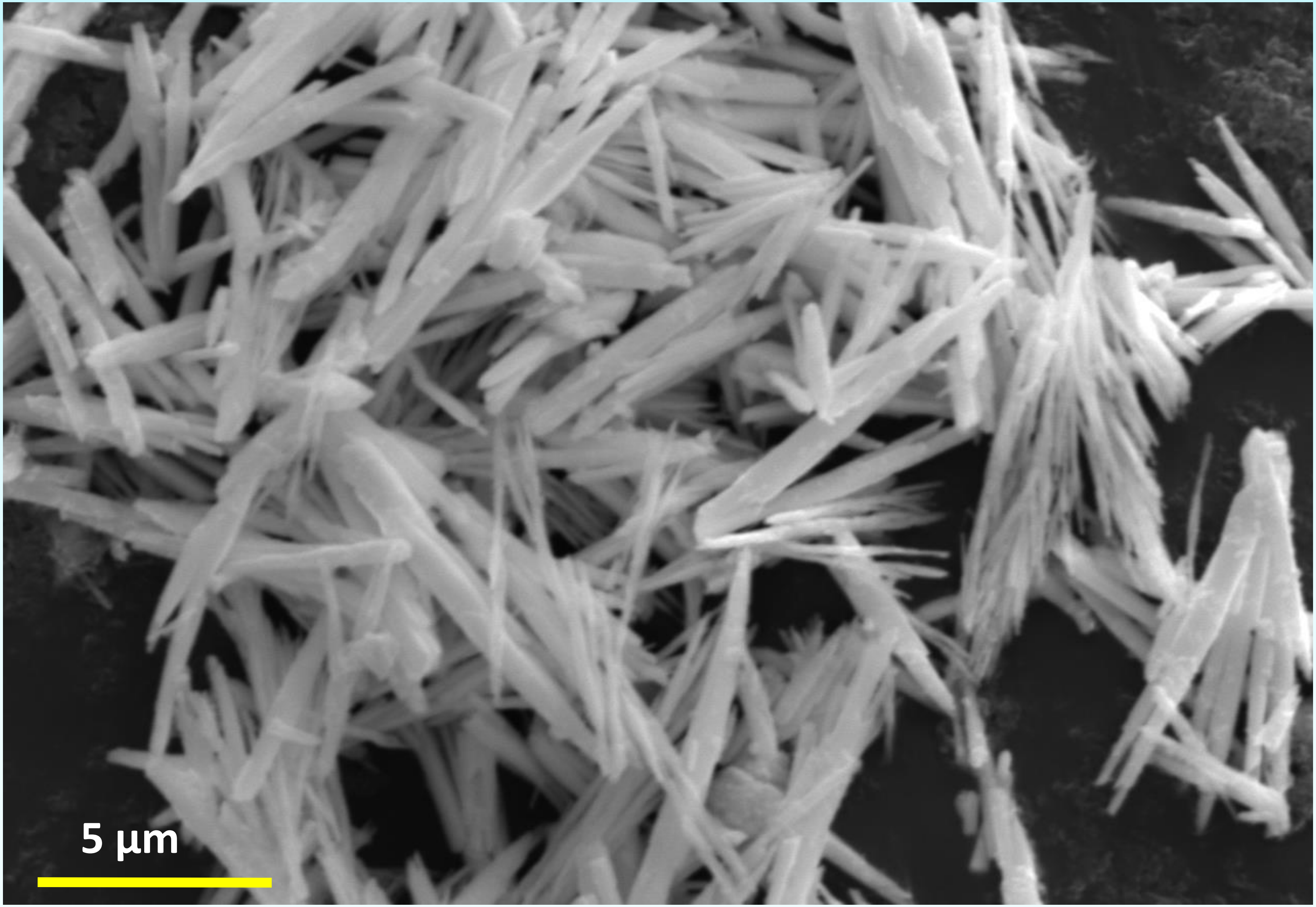
Stability of Anatase phase > 800 °C.

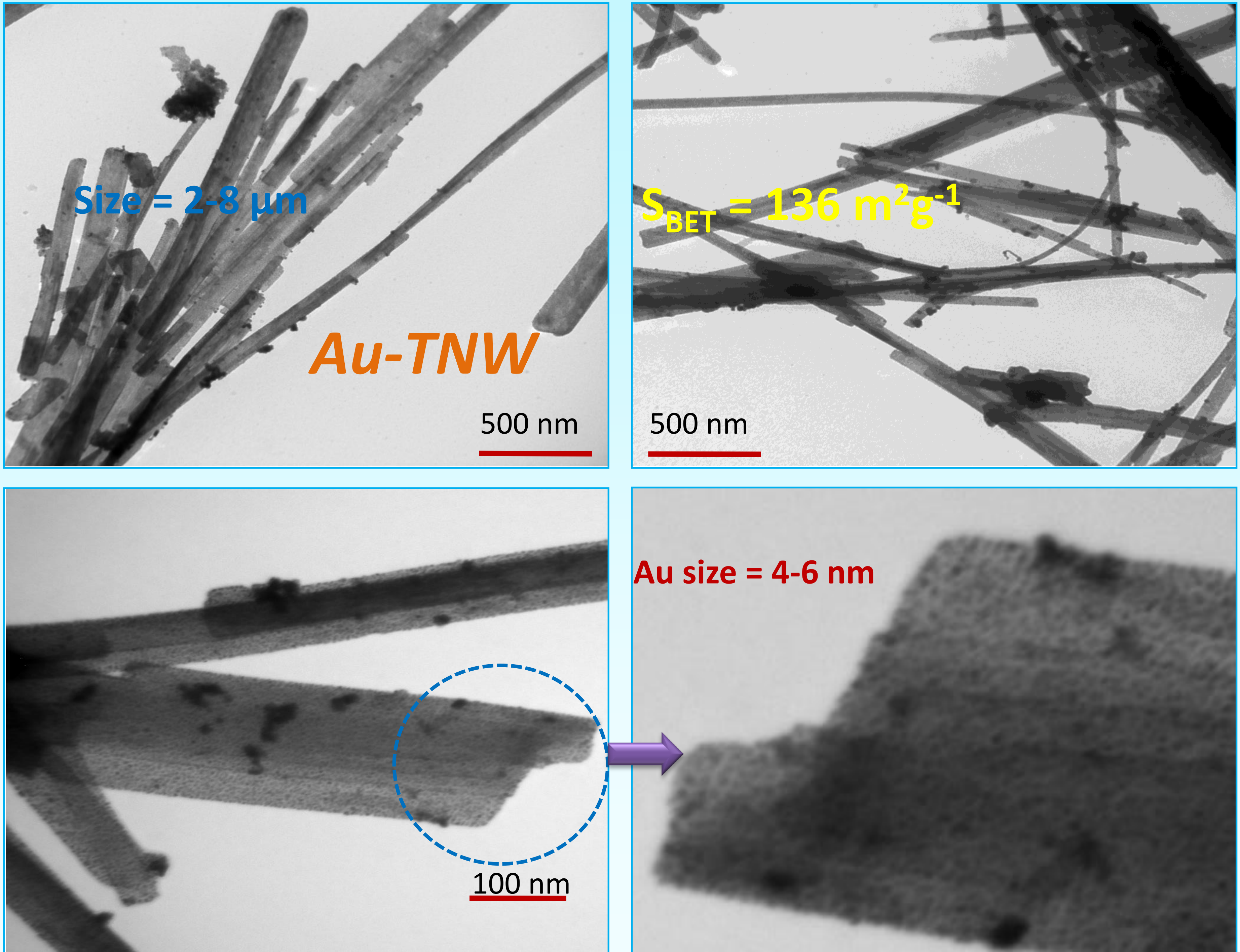
Increment in photocatalytic activity with rise of calcination temperature for C-2 to C-9 catalyst.

Higher activity than P25-TiO_2.

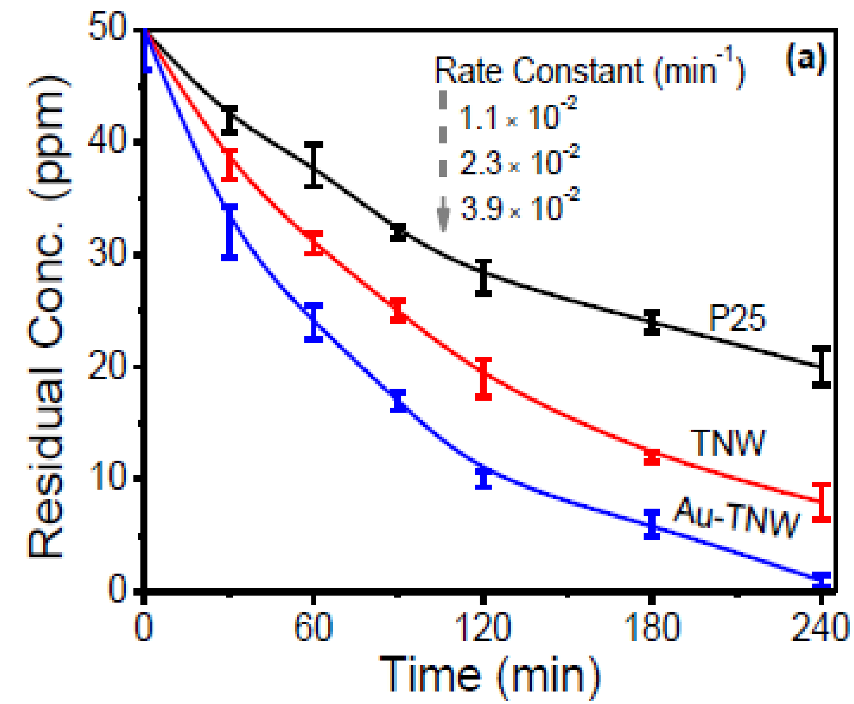
No detrimental influence of decrease in S_{BET} and increase in anatase crystallite size for degradation of methyl parathion.

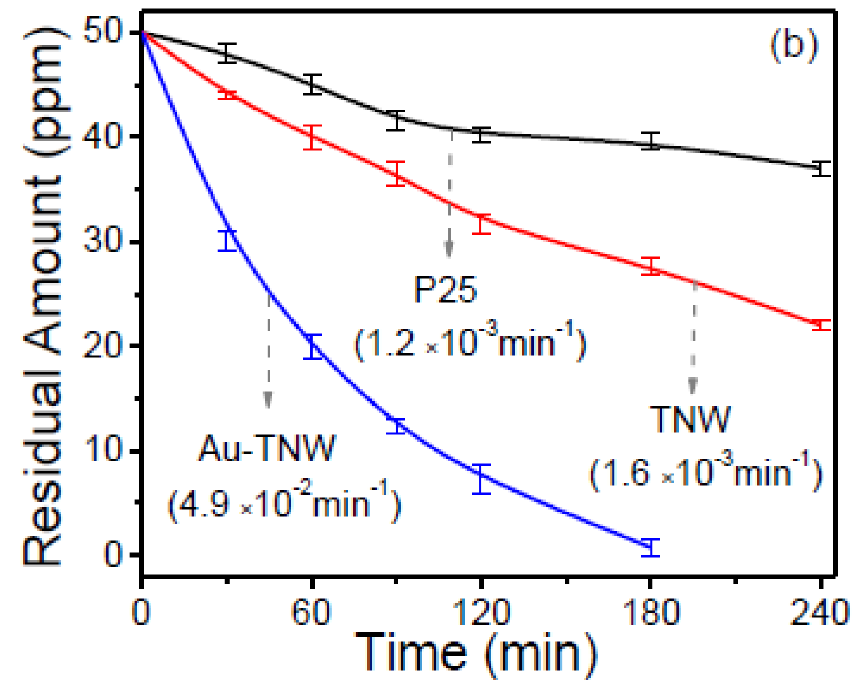
Preparation and characterization of TiO_2 nanowires for improved photocatalytic under sun light irradiation

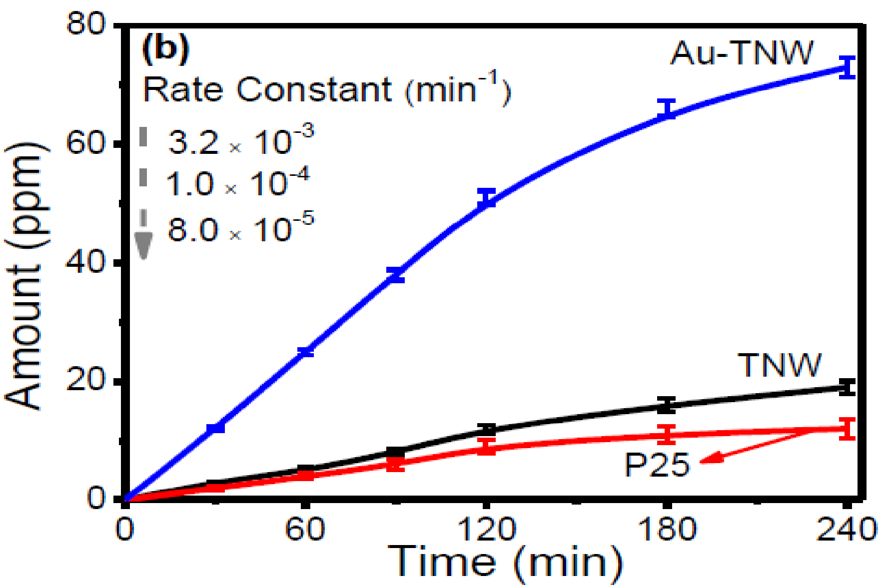


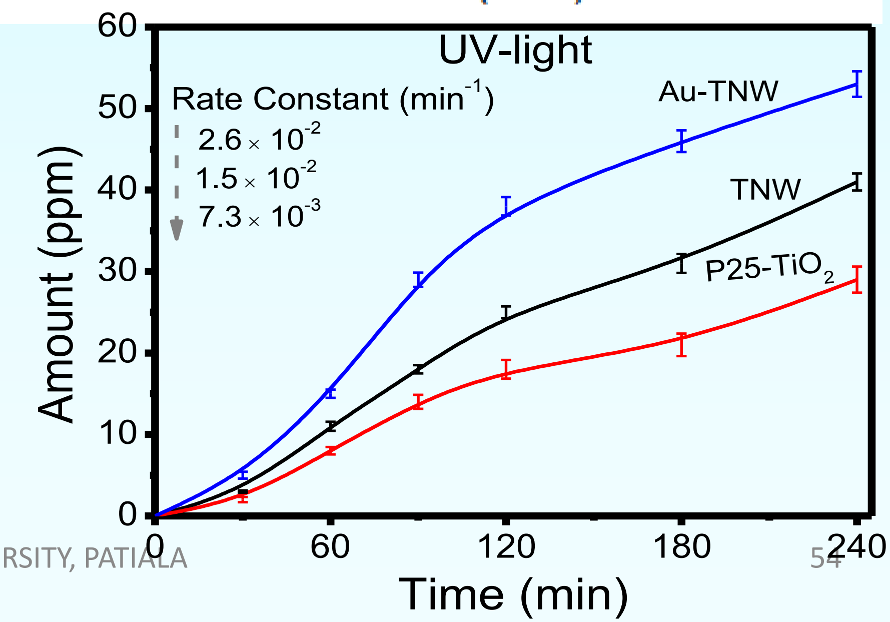

Size = 2-8 μm
Au-TNW
500 nm
S_{BET} = 136 m^2g^{-1}
500 nm
100 nm
Au size = 4-6 nm

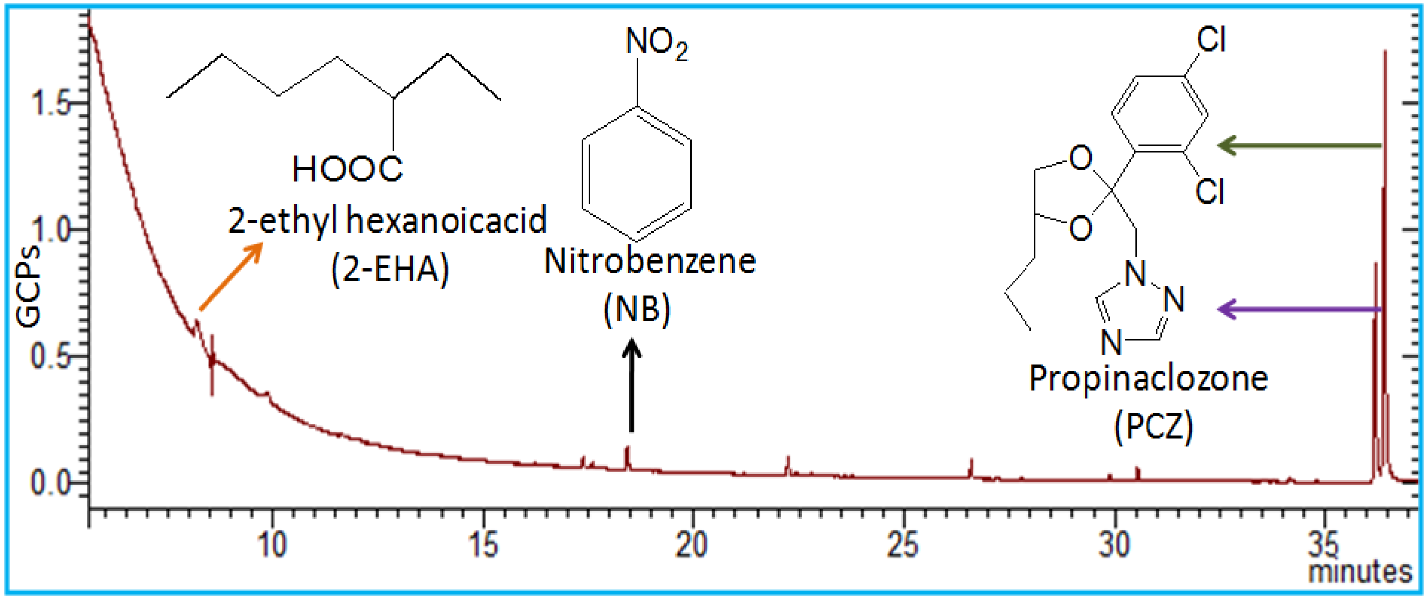
Photocatalytic activity

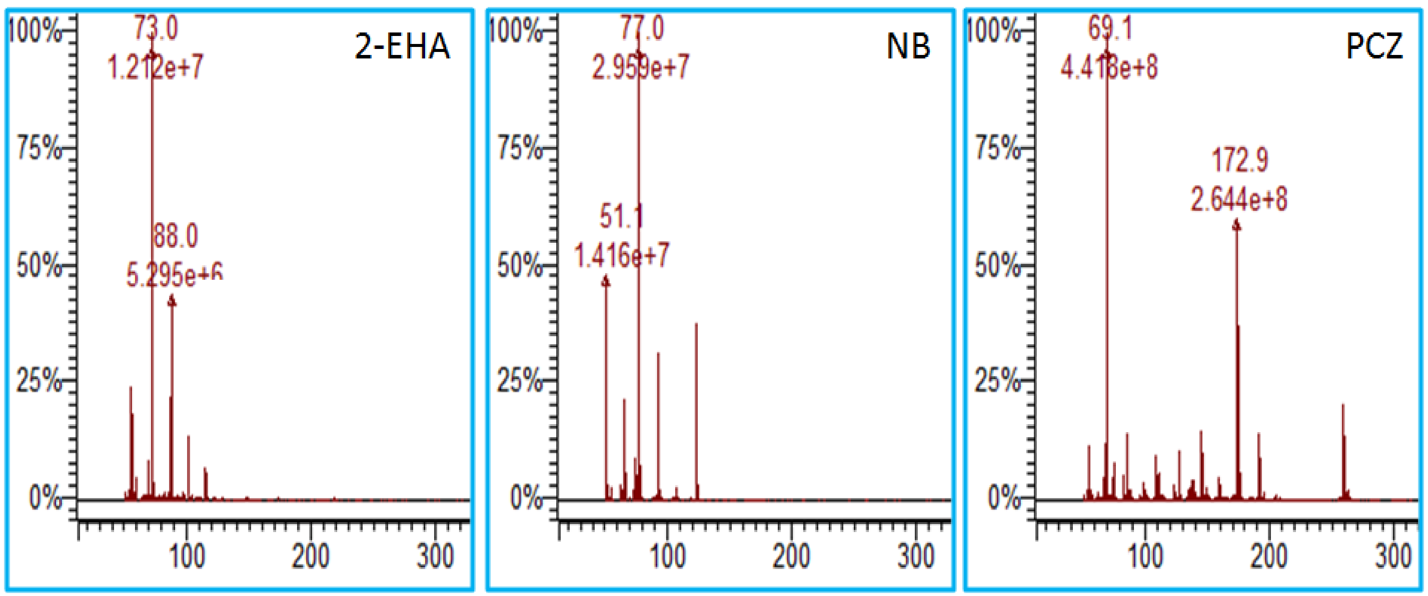








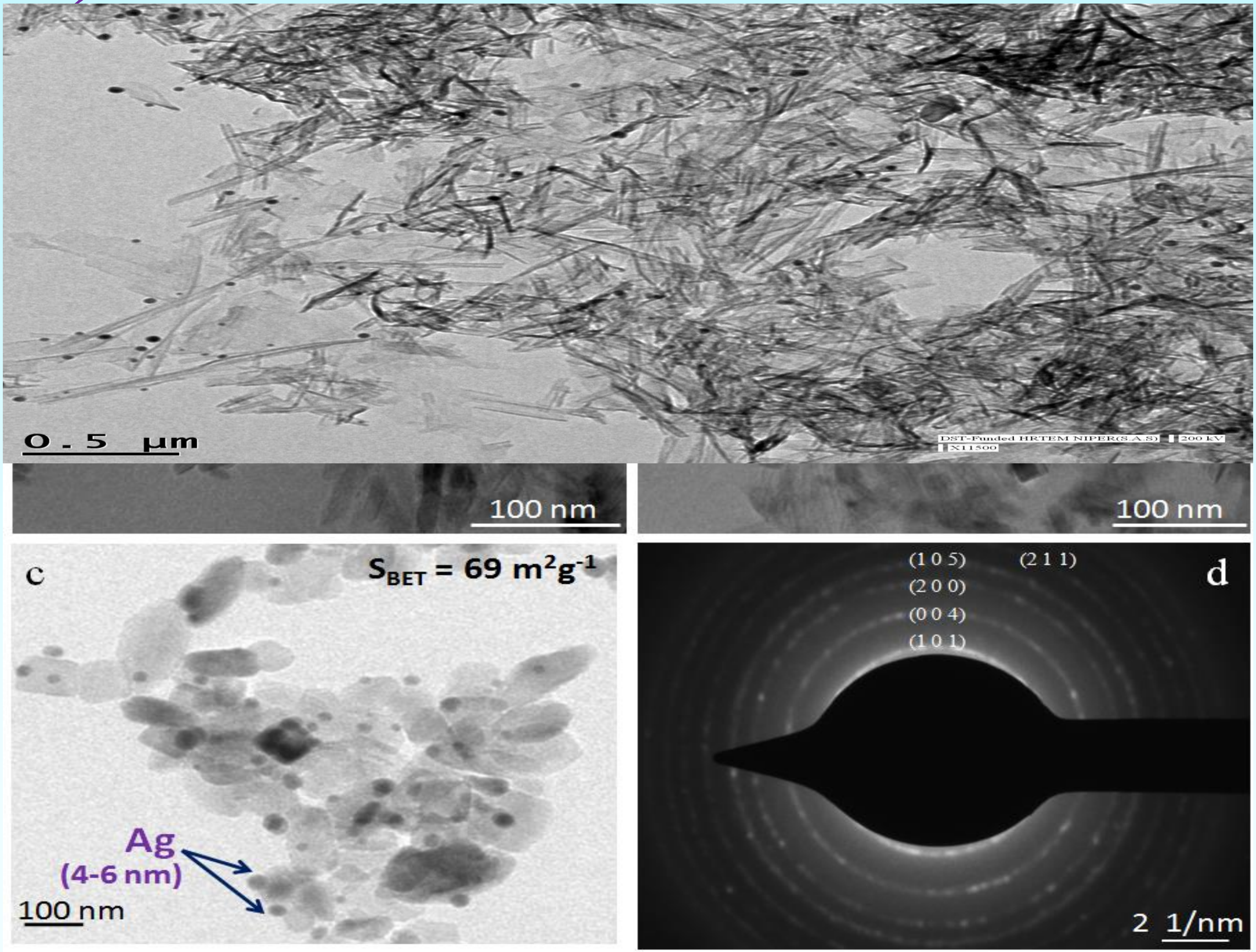




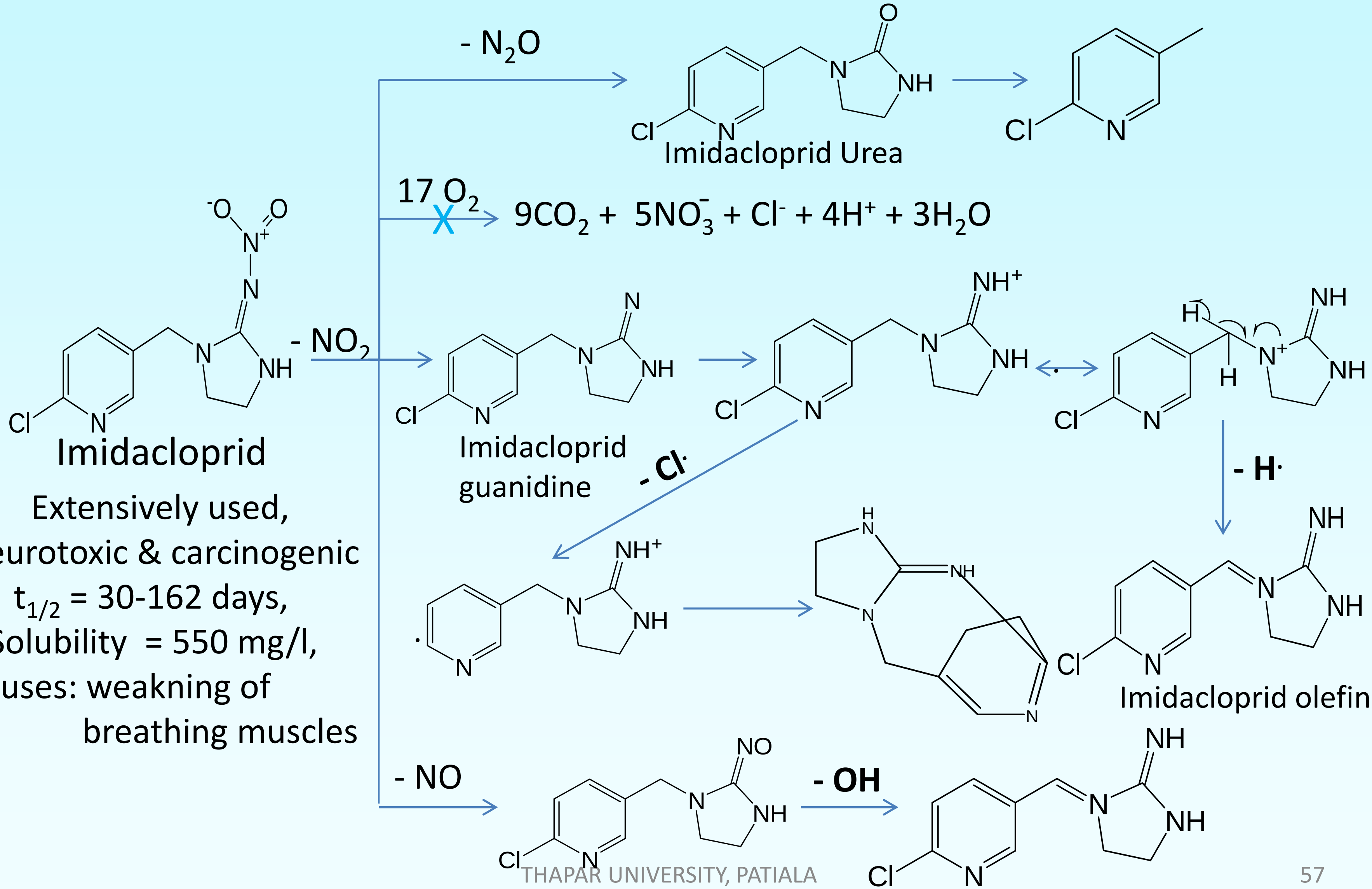
Conclusion:
Higher relaxation time of photoexcited charger carriers resulted into higher catalytic for bare TNW and Au-TNW in comparison to P25-TiO_2.

Conclusion: Mechanistic study for mineralization of imidacloprid was proposed; Presence of intermediates (I-2, I-4and I-6) after 180 min of reaction explains the lack of stoichiometric mass balance.

TiO_2 Nanorods

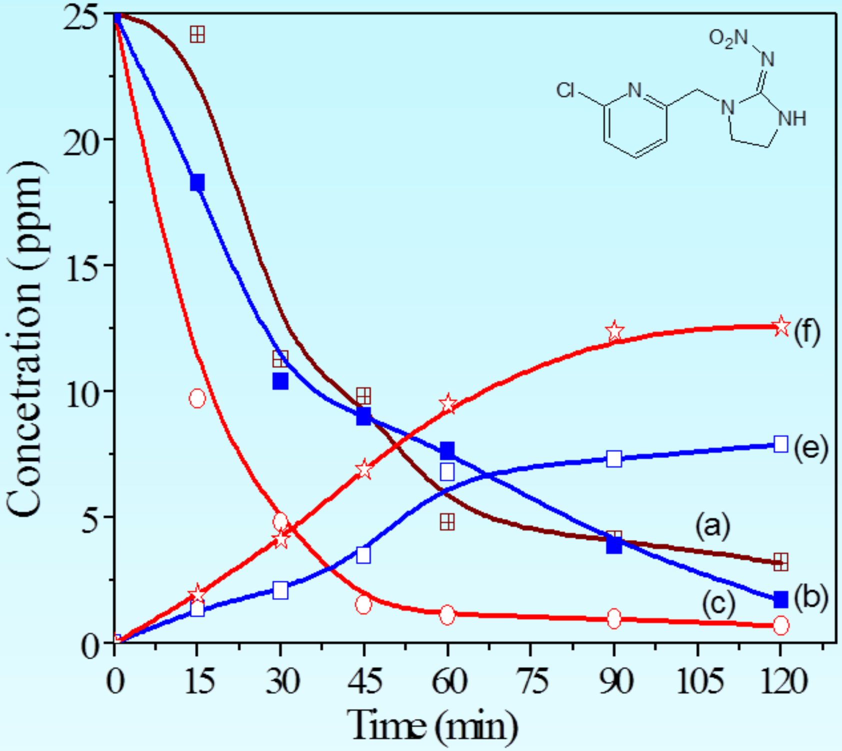


Natural pathway for Imidacloprid degradation

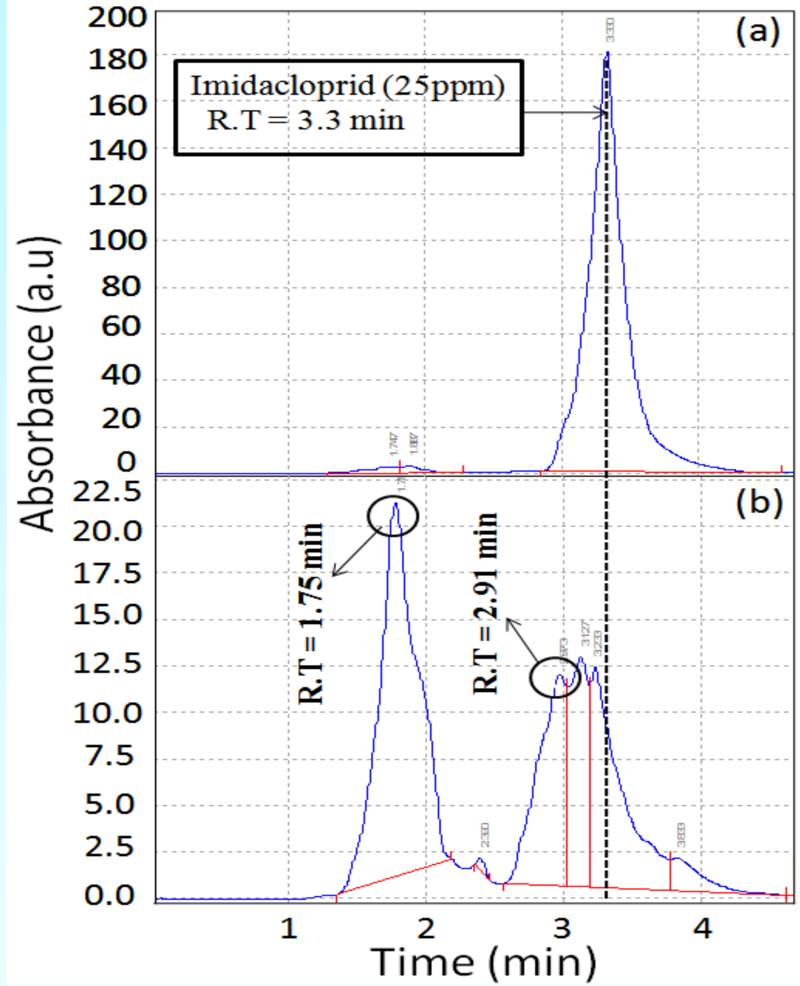


Extensively used,
Neurotoxic & carcinogenic
$t_{1/2}$ = 30-162 days,
Solubility = 550 mg/l,
Causes: weakning of breathing muscles

Photocatalytic activity



Photodegradation of aqueous suspension of imidacloprid (25 ppm) and (a) P25-TiO2, (b) titania nanorod, (c) sodium titanate nanotube particles and CO_2 produced by (d) titania nanorod and (e) sodium titanate nanotube.



HPLC chromatograph for (a) authentic imidacloprid and (b) its photooxidation by TNT after 120 min of UV-light irradiation.

Conclusion: **Change in shape of titania nanoparticles alters electro-kinetic properties.**

Higher Surface area of nanotubes resulted into its higher photoactivity.

Summary and Conclusions

Photocatalytic degradation of pesticides and polycyclic aromatic hydrocarbons by metal doped titania nanoparticles could be effective under sun light amd more greener r**oute**

In summary, present work demonstrated thatdifferent sizes, shapes of titania/titanate nanoparticles and studied the complete decomposition of pesticides (imidacloprid, sulfosulfuron, propiconazole and methylparathion) and PAHs (naphthalene and anthracene)

Crystalline sodium titanate nanorods exhibiting comparable photoredox activities to that of P25 for photoreduction of m-DNB and photooxidation of sulfosulfuron. TNW displayed much higher PCA than P25 for decomposition of propiconazole under UV- and sun-light,

Ag-photodeposited TNT is an efficient catalyst for the decomposition of IMI to CO2 and inorganic ions. The formation of number of identified intermediates reveal the complexity of photocatalytic process, suggesting the existence of various oxidation routes and non-specific attack of hydroxyl radicals that result in multi-step and interconnected pathways for decomposition of IMI.

TiO2 crystal phase played a vital role for superior photoactivity for MP degradation, the detrimental influences of decreased surface area, increased particle size and crystallite size are not observed for the C-2 to C-9 catalysts that were thermally treated at high temperatures.

Publications of this current presentation:

Applied Surface Science, 280 (2013) 366–372,
RSC Advances, 4 (2014) 51342 - 51348.
RSC Advance, 4 (2014) 24704-24709.
Journal of Nanosci. Nanotech. 14 (2014) 1–9.
Journal of Agricultural and Food chemistry 62 (52), 12497-12503
Environmental Science and Pollution Research 20 (9), 6521-6530
Environmental Monitoring and Assessment, 185 (2013) 6459–6463
Environmental Monitoring and Assessment, 185 (2013) 6291–6294
Journal of Industrial and Engineering Chemistry, 31, 223-230, 2015.
Environmental Science and Pollution Research, 19 (2012) 2305–2312.
Materials Chemistry and Physics, 136 (2012) 21-28.
New Journal of Chemistry, 39 (2015) 5966-5976.
Journal of Molecular Catalysis A: Chemical 396 (2015) 15–22.
Journal of Molecular Catalysis A: Chemical, 391 (2014) 158–167.
Chemical Engineering Journal, 246 (2014) 260-267.
Environmental Science and Pollution Research, 20 (2013) 3956–3964.

Total SCI publications: 87, Citations: 1413, h-index= 16

Project: DST/CSIR/UGC (~ 1.7 Crores) 8 Ph.D. Guided, 7 Persuing

Recent Publications:

R. Kaur and B. Pal, *J. Mol. Catal. A. Chem.*, 395 (2014) 7-15.
N. Gupta and B. Pal, *Chem. Eng. J.*, 246, 2014, 260-267.
J. Kaur and B. Pal, *Catal. Comm.*, 53, 2014, 25–28.
J. Kaur and B. Pal, *Chem. Commun.*, 2015, 51, 8500-8503.
R. Kaur and B. Pal, *New J. Chem.*, 39 (2015) 5966-5976
A. Monga and B. Pal, *RSC Advance*, 2015, 5, 39954–39963.
R. Singh and B. Pal, *ChemPlusChem.*, 5, 851–858, 2015.
A. Monga and B. Pal, *New J. Chem.*, 39 (2015) 304-313.
B. Pal and B. Pal., *Chem. Eng. J.*, 263, 2015, 200–208.
R. Kaur and B. Pal, Appl. Catal. A Gen., 491, 2015, 28–36.
I. S. Grover, S. Singh and B. Pal, *RSC Advance*, 2014, **4**, 24704-24709.
I. S. Grover, S. Singh, B. Pal, *J. Agri. and Food Chem.* 2014, 62, 12497−12503.
S. Sareen, V. Mutereza, S. Singh and B. Pal, *RSC Advances*, 2015, 5 (1), 184-190.
S. Sareen, V. Mutreja, S. Singh and B. Pal, J. Colloid and Inter. Sci., 461 (2016) 203–210.

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School of Chemistry & Biochemistry

M. Sc. (Chemistry)

M.Sc. (Biochemistry) and Ph.D.

- 30 seats + (3 FN/NRI seats) in each stream
- Six month Project thesis
- Special Coaching for NET, & GATE examinations
- Recruitment opportunity in national research labs & research projects
- Merit scholarships for toppers of M.Sc. Programme

ELIGIBILITY:

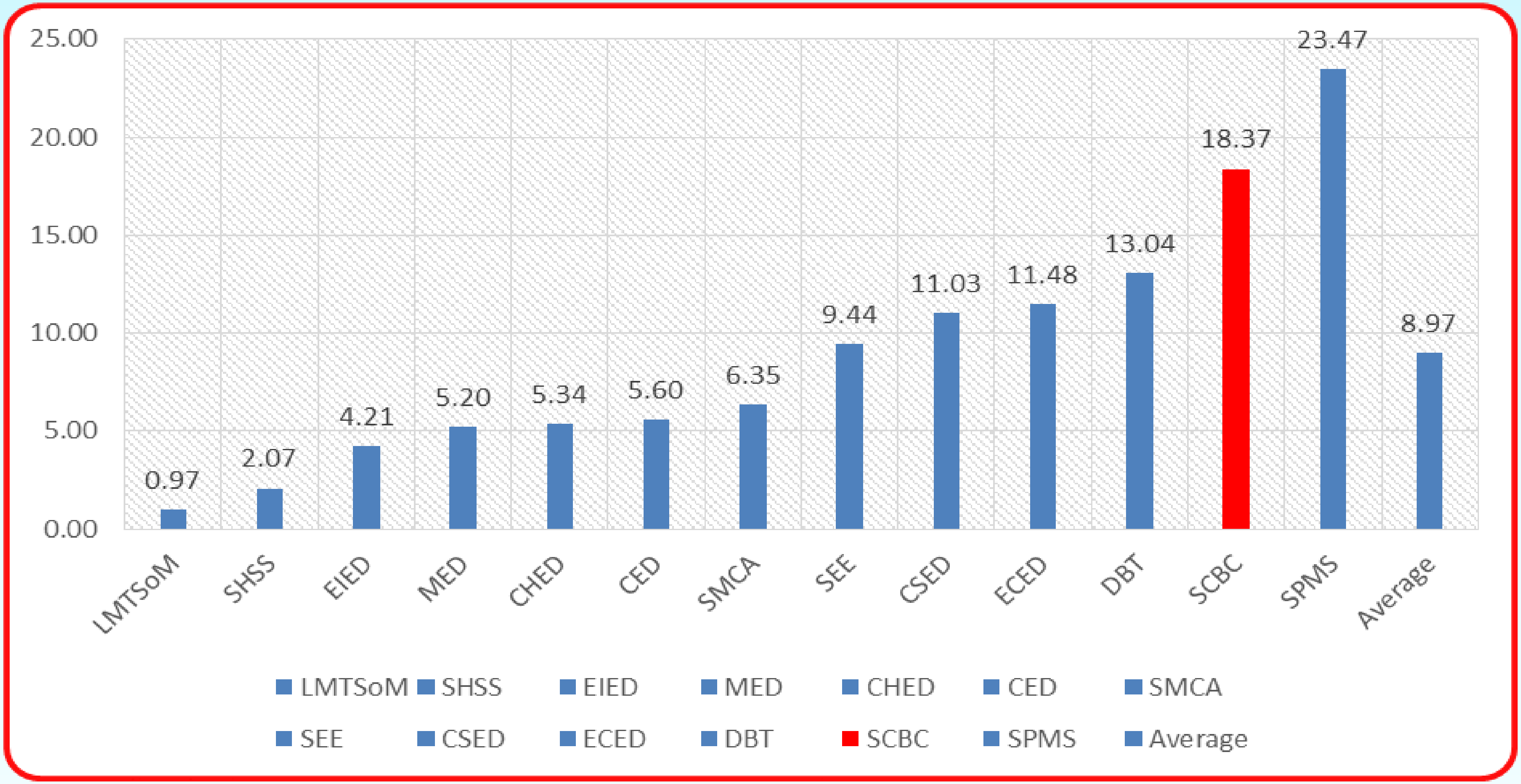
B.Sc. Degree with 60% marks (55% for SC/ST students) and chemistry/biochemistry as one of the subjects.

Selection Procedure:

Admissions shall be made on the basis of marks obtained at 10th, 12th and graduation (aggregate marks up to second year/four semesters will be considered)

Research Achievements of the School

- **School consistently features in top 3 departments/School of TU in academic research score (on the basis of publication + research funding + Ph.D. thesis guidance)**
- **In faculty strength, SCBC in bottom 3 of TU**



Research Achievements of the School of Chemistry & Biochemistry

- No. of Publications: 450
- Average impact factor per publication: 2.5
- No. of on-going Major Research Projects: 15
- Grant-in Aid (on-going Projects): **~ ₹ 30 million (Euro 4,64,000)**

- No. of completed Major Research Projects: 24
- Grant-in Aid (completed Projects): **~ ₹ 400 million (Euro 5,90,914)**
- No. of Ph.D on-going: 50
- No. of Ph.D completed: 35

Research profile of SCBC

RESEARCH AREAS

- Nanomaterials & Photocatalysis
- Chemical Sensors, Biosensors
- Biocatalysis & Biotransformation
- Biofuels & Catalysis
- Synthetic Organic Chemistry
- Biophysical and Bioinorganic Chemistry
- Medicinal Chemistry
- Supramolecular chemistry
- Advanced Nanomaterials
- Metal Hydrides, Organometallic Chemistry

Thanks

Organizing Committee ------------Pollution Control 2016

School of Chemistry and Biochemistry, Thapar University

Ph.D.Student:

Nidhi, Rohit, Inder, Rupinder, Bhupinder, Anila, Jaspreet, Shweta, Reyees, Tanushree, Projapot, Upraaj, Manpreet, Sakshi, Ritika, Smriti

Project: DST-Nanomission, UGC and CSIR

(Total 1.70 Crores)