Titania-based Nanocomposites for typical VOCs degradation

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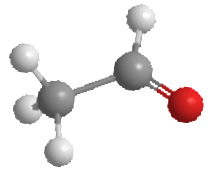
1 Background

Indoor Air Pollution---interior sources, external sources

Typical Indoor Pollutants (TVOC)

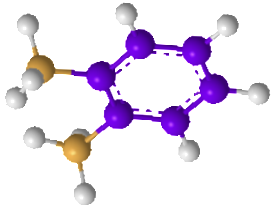
Typical VOCs : High reactivity、precursors for SOA and O_3, different in polarity and functional groups

Aldehydes



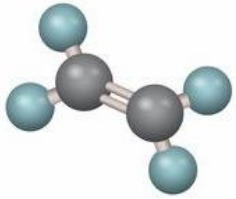
Acetaldehydes, formaldehydes...

Benzene series



Benzene, m/p/o-xylene....

Hydrocarbon



Ethylene, isoprene....

1 Background-Photocatalytic reaction

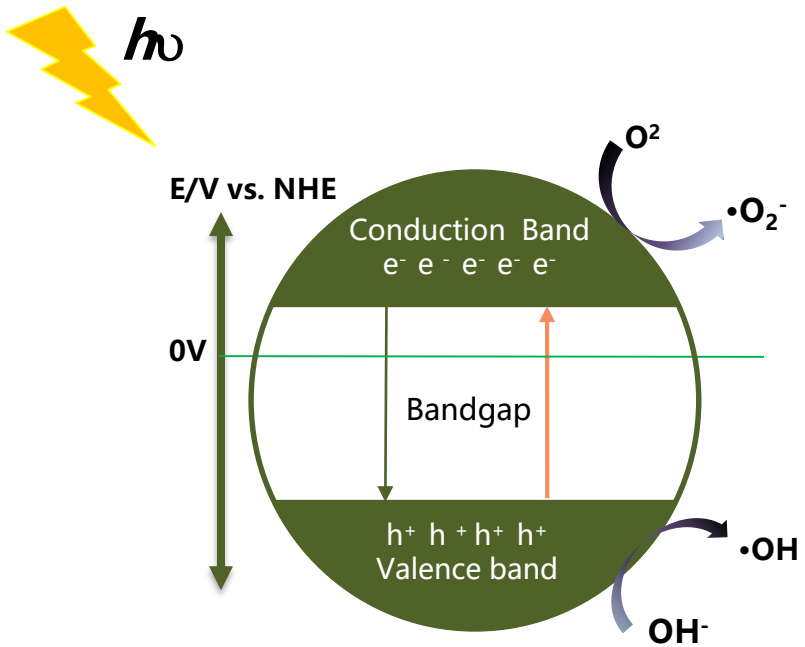
Elimination of VOCs

- thermocatalytic
- O_3 oxidation
- adsorption
- photocatalytic

photocatalytic →

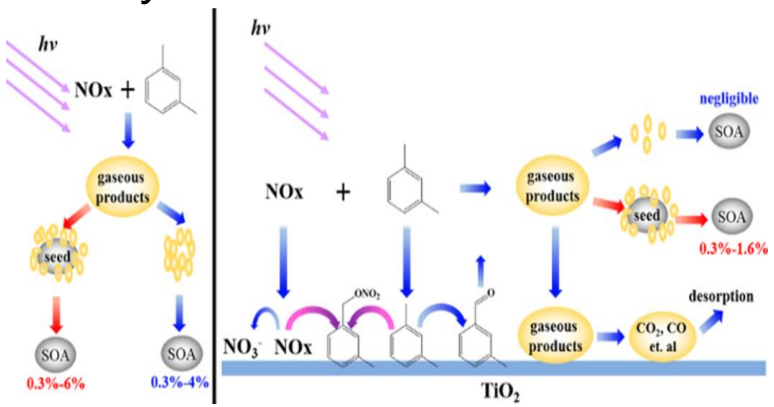
- RT operation
- Utilization of sunlight
- Safety
- Low cost

Basic mechanism



TiO_2 photocatalysts

- High oxidation potential, environmental friendly



- Capable of suppressing the formation of SOA

Environ. Sci. Technol. 2018, 52, 11612–11620

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1 Background--TiO_2 Photocatalyst

Light absorption → **Seperation of e^--h^+** → Interfacial reactions

Band gap： 3.2eV

Direct-band-gap;

Excited by UV light

Recombination of e^--h^+

Extends the range of spectra response

Effective transportation of free electrons

Metal nanowire-TiO_2 heterojunctions

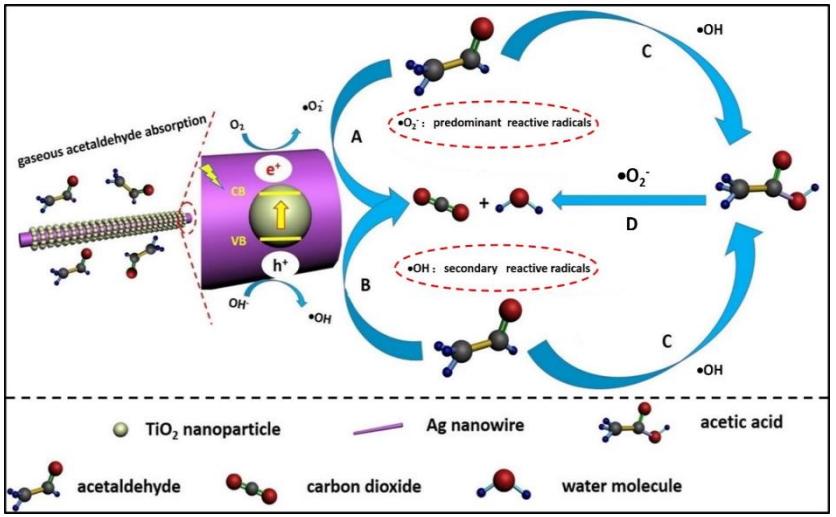
Heterojunction structures;

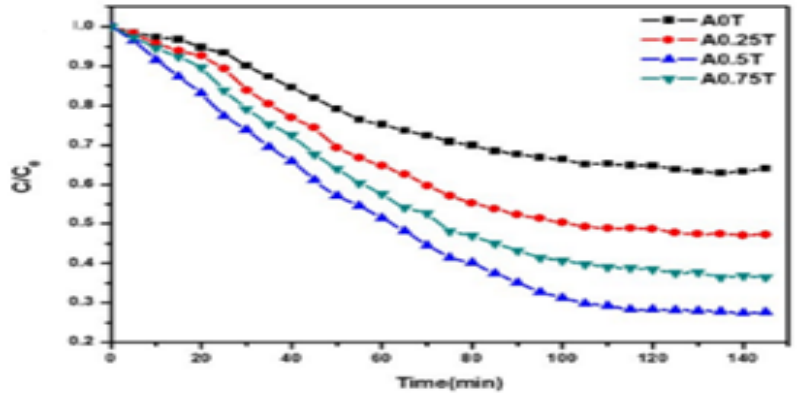
SPR effect

Conductivity

doping

Effective degradation of acetaldehyde





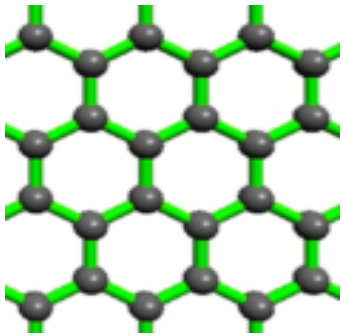
Applied Surface Science 408 (2017) 117–124

Chemical Engineering Journal 341 (2018) 83–92

1 Background--TiO_2 Photocatalyst

Light absorption → Seperation of e^- - h^+ → **Adsorption** → **Radical reactions**

Carbon nanostructures



Funtional groups | **Carbon skeleton** | **High density of electrons**

Carbon Nanostructure-TiO_2

Surface optimization | **Inhibite the recombination of e^--h^+**

Polarity of the Surface

Adjustable for the adsorption of different types of VOCs

Optimize the surface functional groups

Formation of radicals

Unclear mechanism

Accelerate the production of radicals

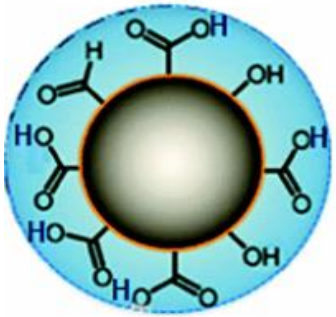
Surface optimization

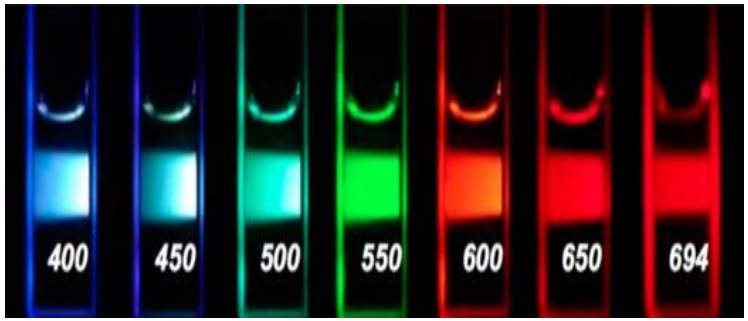
Effective adsorption of VOCs

Improve the amount of radicals

2.1 CQD-TiO_2 Photocatalyst

Carbon dots





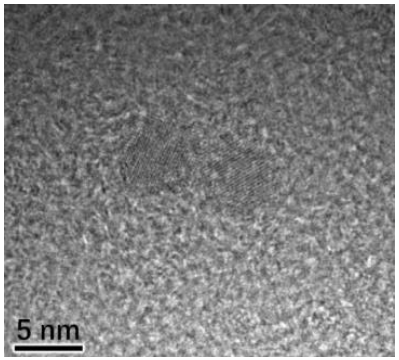
Up-conversion

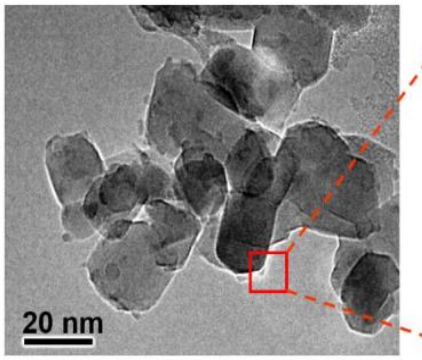
Abundant funtional groups

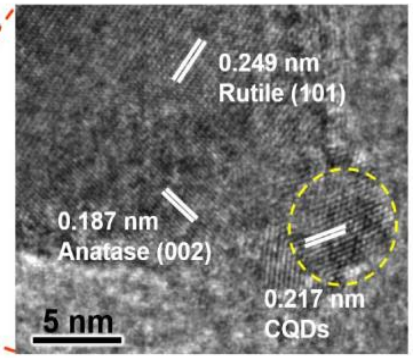
Electron donor

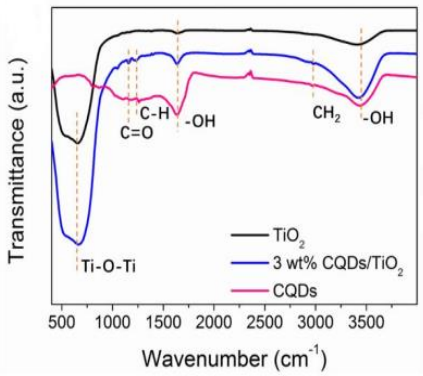
Low cost

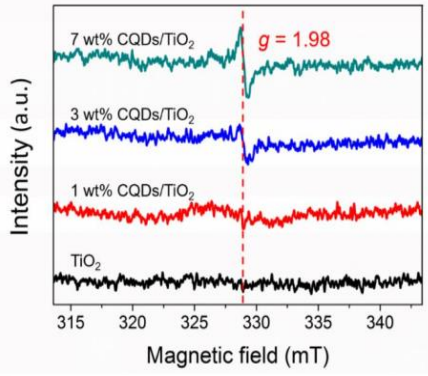
CQD-TiO_2

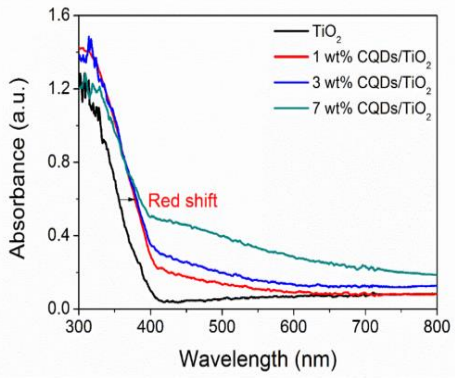












- Size of CQD----5 nm;
- The formation of Ti^{3+} due to the interfacial tranportation of electrons;
- Red-shift of the adsorption edge

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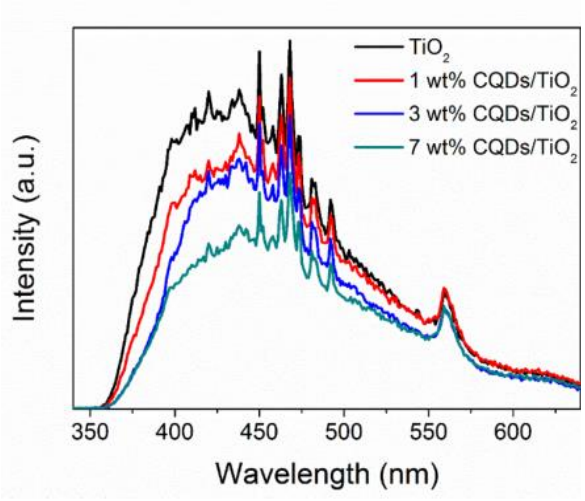
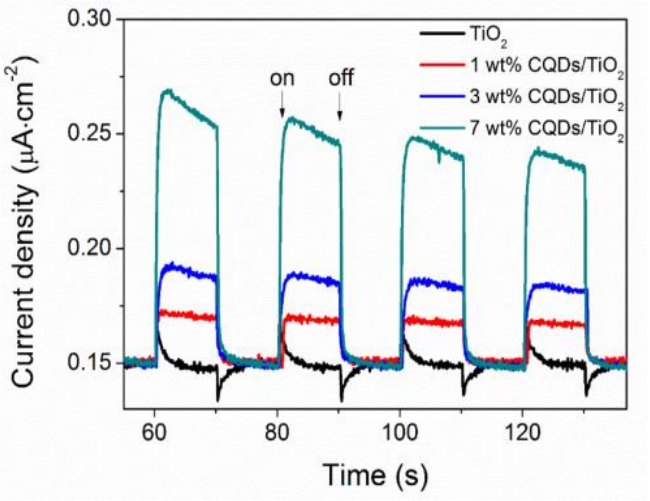
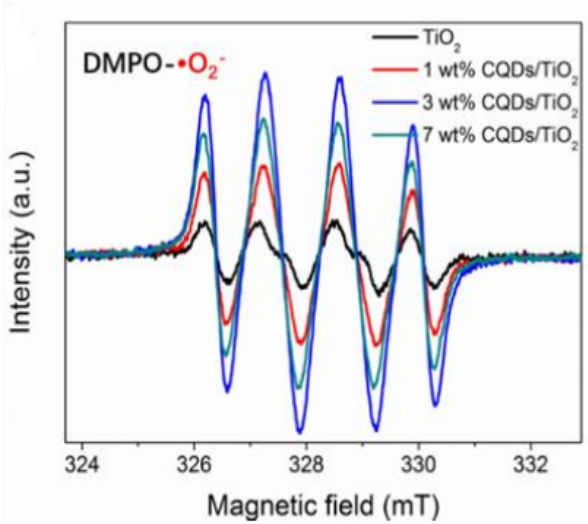
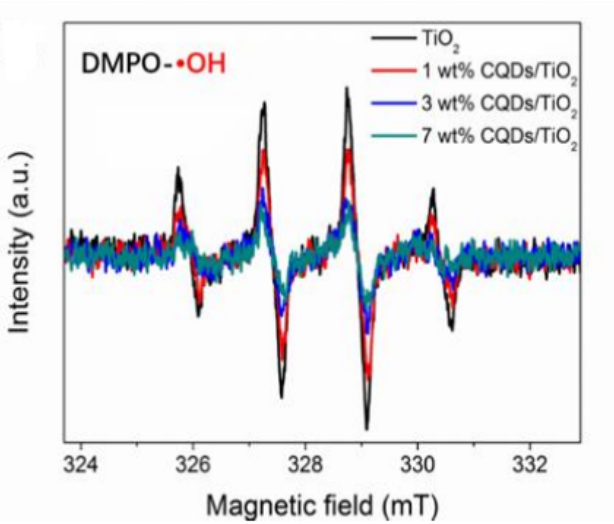
2.1 CQD-TiO_2 Photocatalyst

Formation of radicals









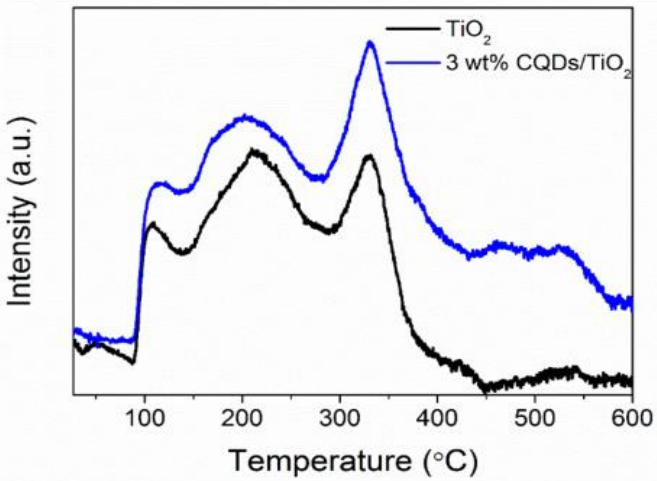
The effective seperation of e^- - h^+

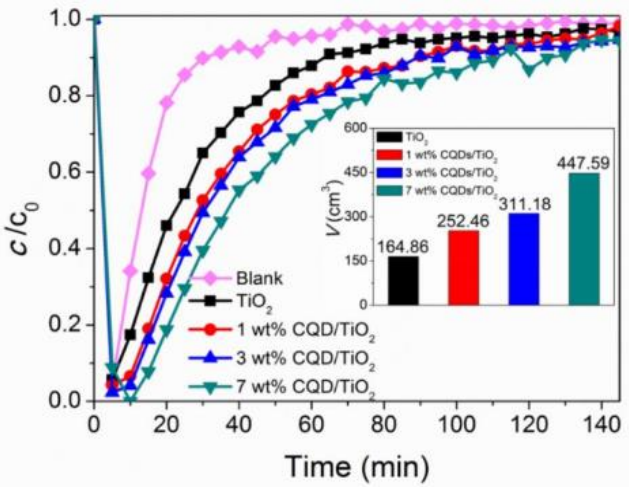
The formation of Ti^{3+}

Accelerate the formation of $\cdot O_2^-$ radicals

2.1 CQD-TiO_2 Photocatalyst

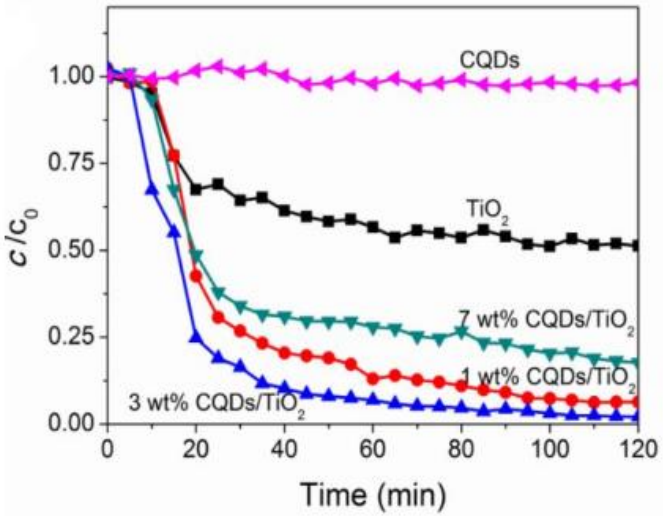
The adsorption of acetaldehyde

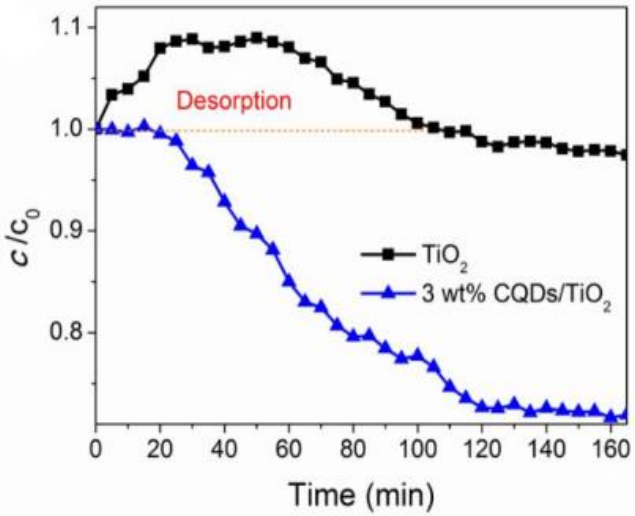




1.7 folds the amount of adsorbed acetaldehyde molecules, 164--- 447 cm^3

The degradtion of acetaldehyde





Almost fully ellimination of gaseous acetaldehyde (~99%),
Sensetive to visible light

Fluorescent light (λ>380 nm, 20 mW cm^{-2})

Visible light (λ>400 nm)

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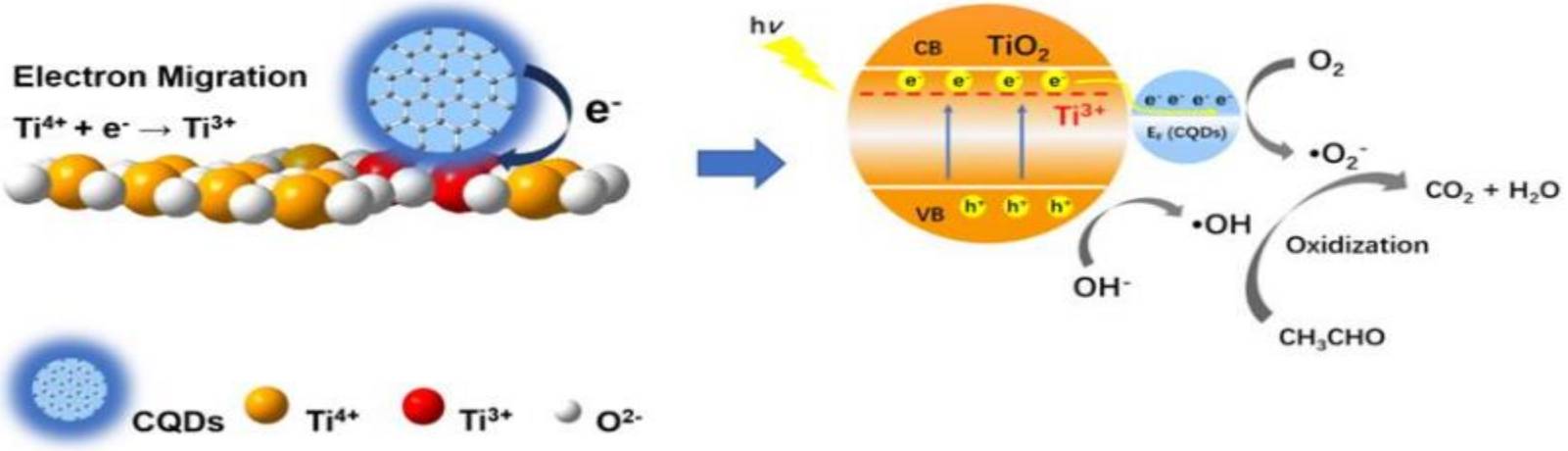
2.1 CQD-TiO_2 Photocatalyst



CQD-TiO_2 Photocatalyst

Electron donor

Abundant surface functional groups

Ti^{3+}

Seperation of e^- - h^+

More $\cdot O_2^-$ radicals

Effective adsorption of pollutants

Highly effective material for the ellimination of acetaldehyde

Hu et al.,Applied Surface Science 440 (2018) 266–274

2.2 rGO-TiO_2 Photocatalyst

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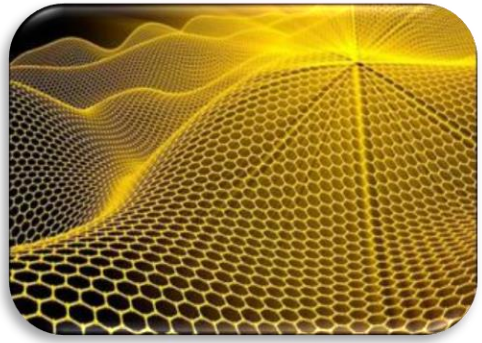
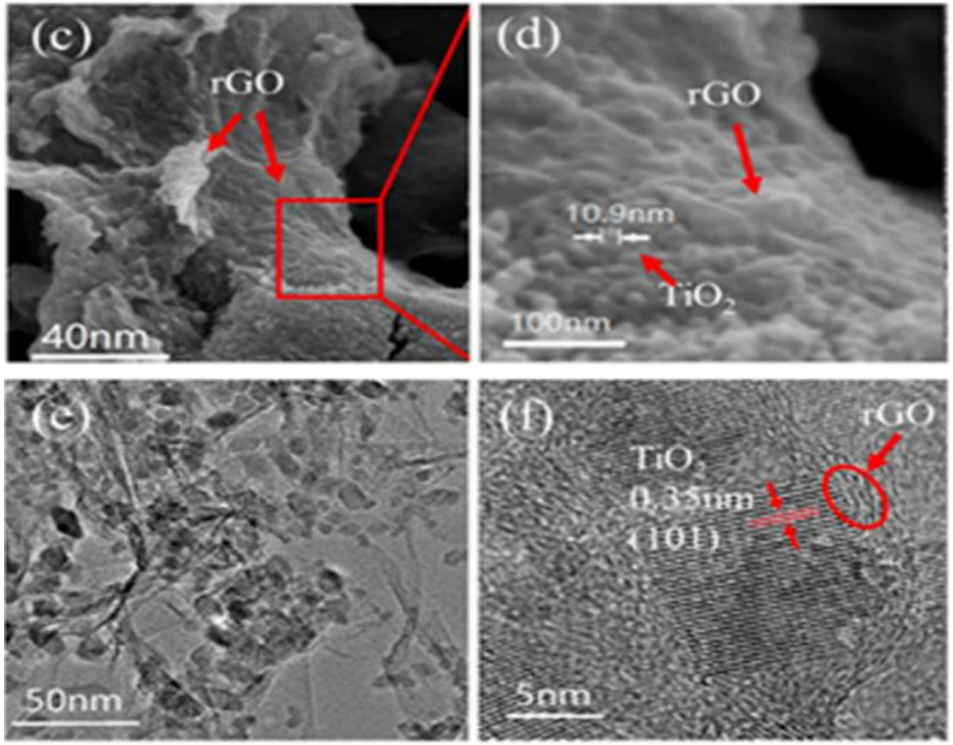


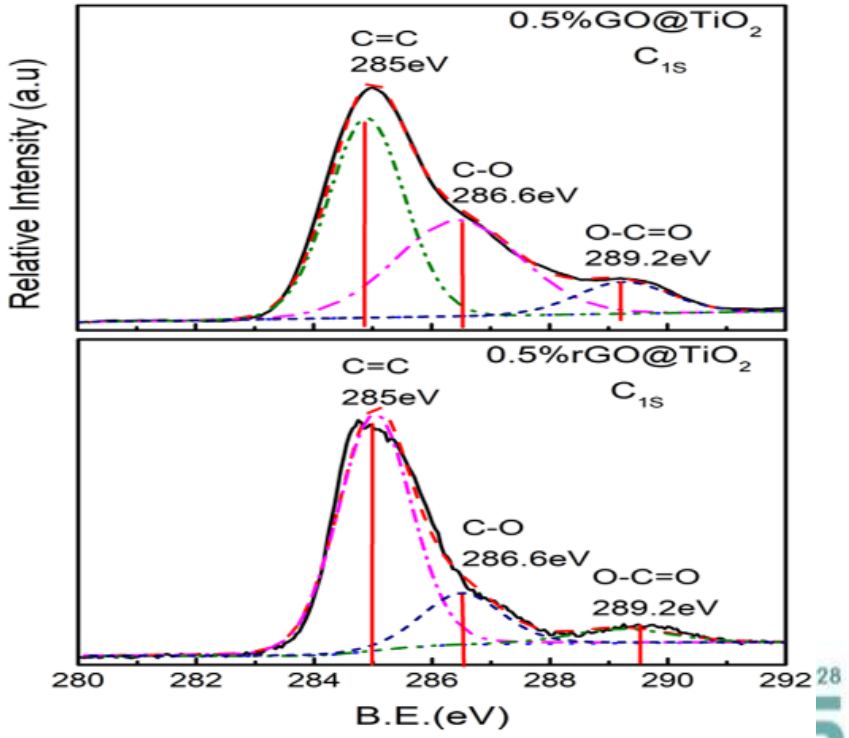
- Large surface areas
- π-π bonds
- 0 band gap
- accesibility

→ rGO-TiO_2 →

- Effective adsorption of pollutants
- Seperation of e^--h^+
- Scalable fabrication

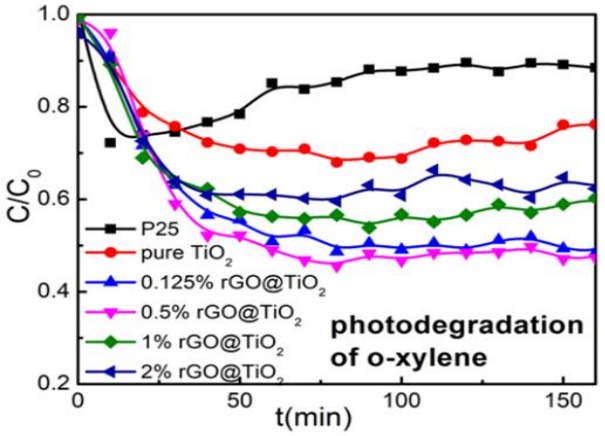
rGO-TiO_2

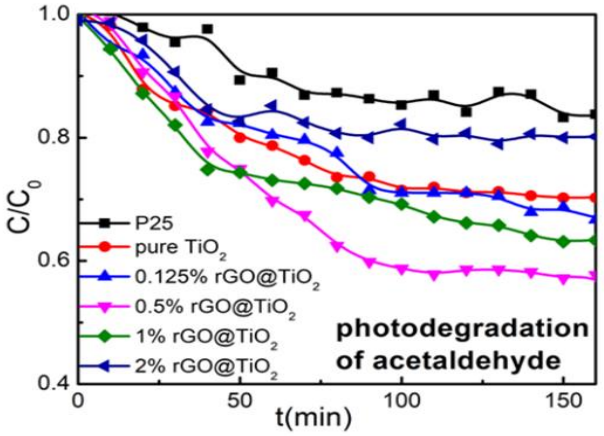


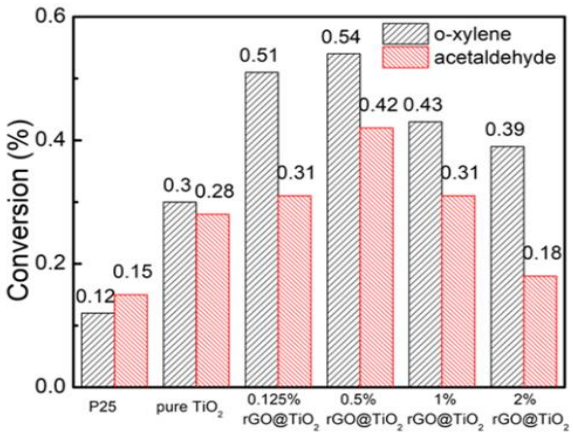


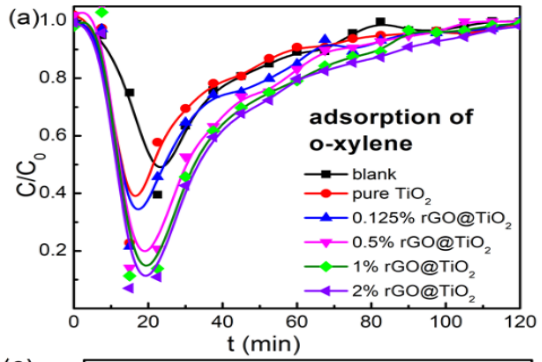
2.2 rGO-TiO_2 Photocatalyst

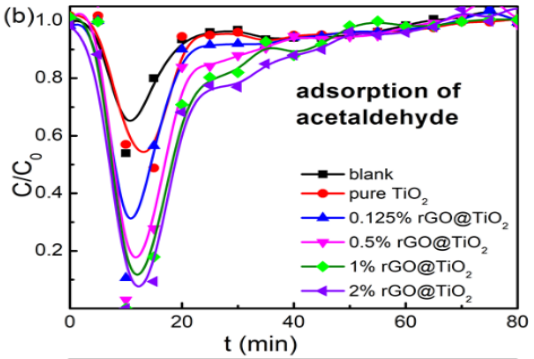
Adsorption & Degradtion of O-xylene & Acetaldehyde

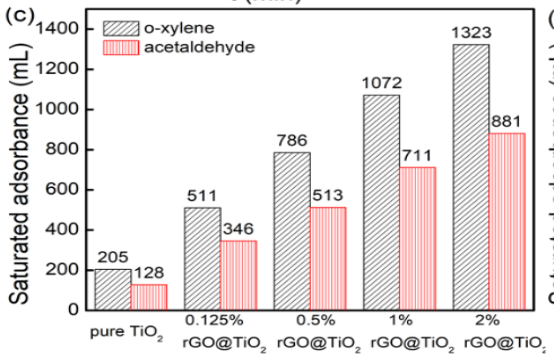


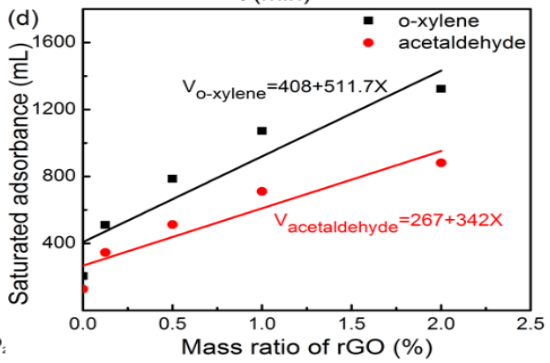












- rGO could benifit the adsorption and degradation of o-xylene and acetaldehyde
- The π-π interaction between rGO and benzene ring makes rGO-TiO_2 more suitable for the adsorption of o-xylene

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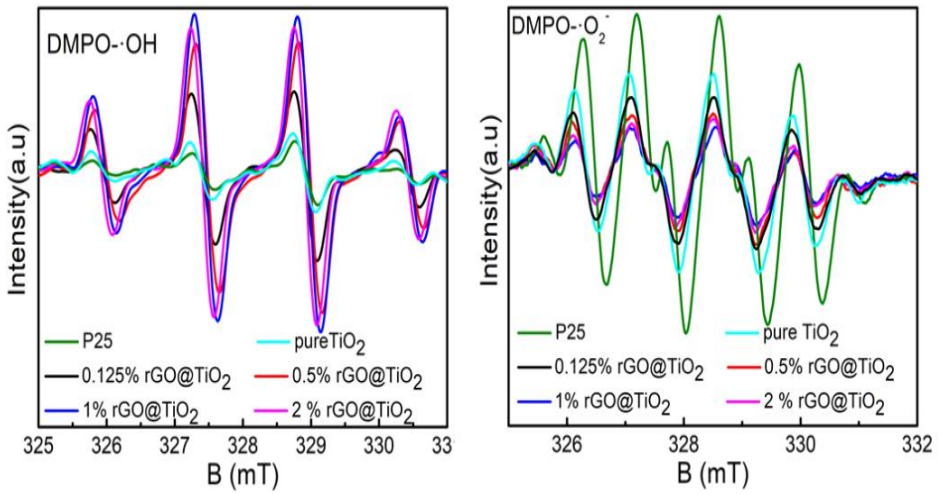
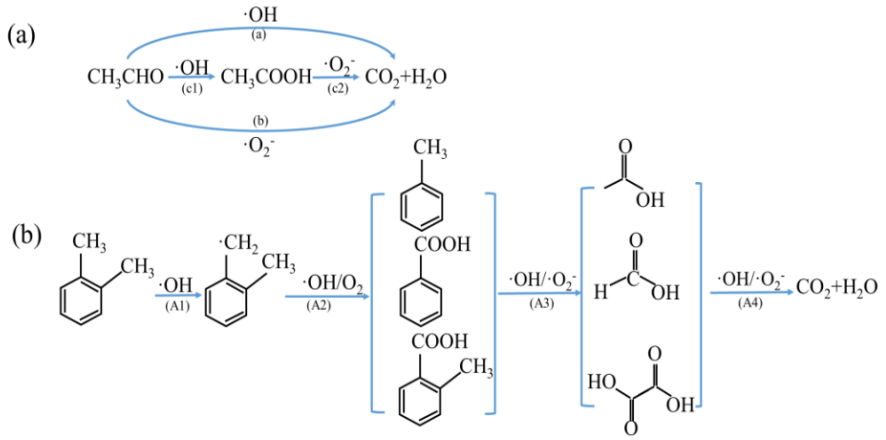
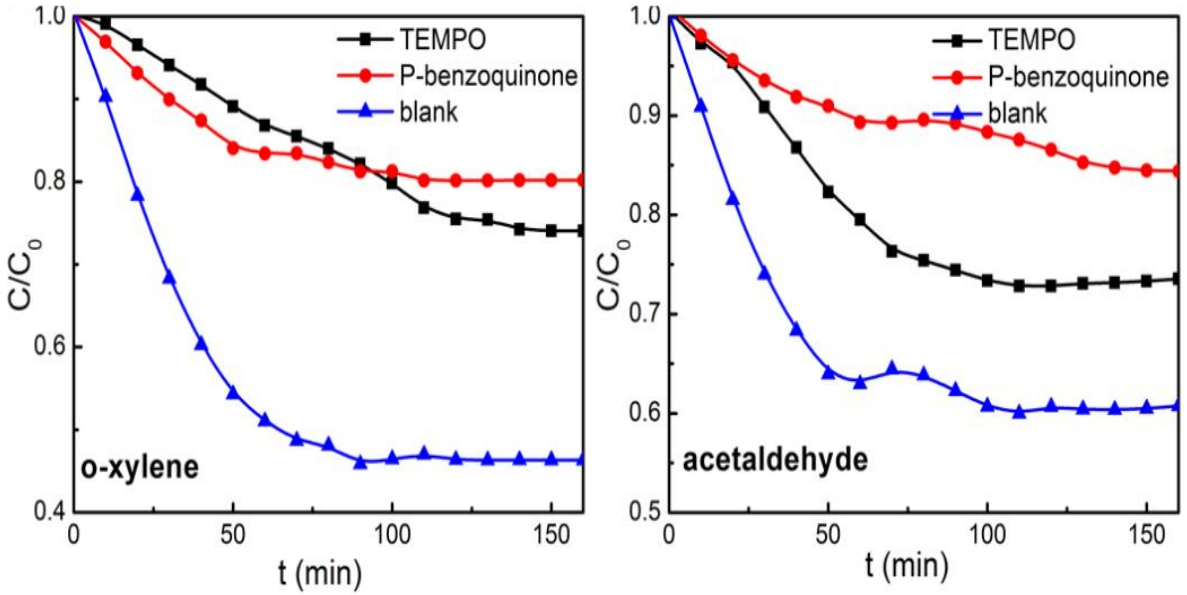
2.2 rGO-TiO_2 Photocatalyst

Radicals & degradation of pollutants







- More ·OH radicals but less $\cdot O_2^-$ radicals,
- Both radicals have similar roles in the degradation of o-xylene,
- $\cdot O_2^-$ is more important for the degradation of acetaldehyde,
- rGO-TiO_2 is more suitable for the ellimination of o-xylene

Lin et al., Chemical Engeering Journal, 2018, 345: 708-718

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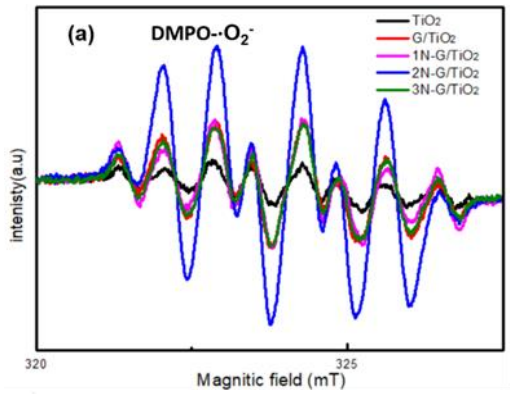
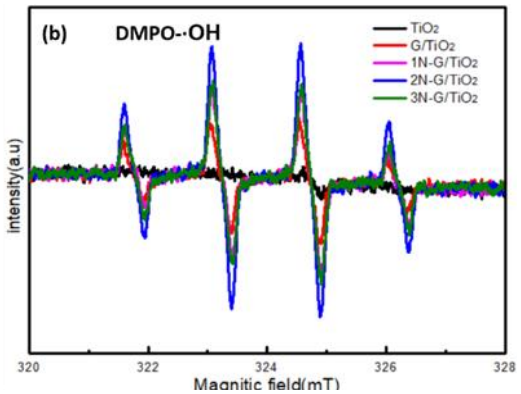
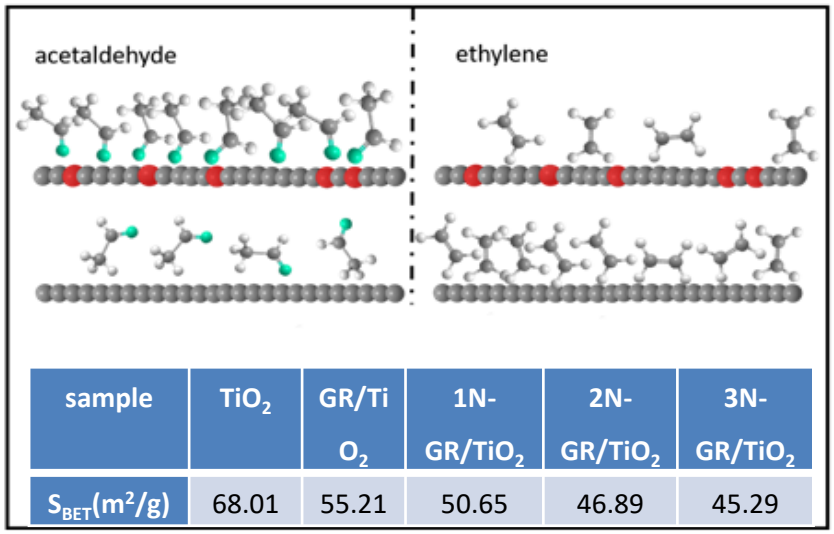
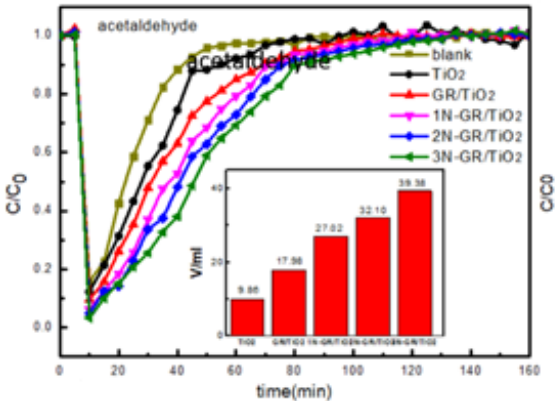
2.3 N-rGO-TiO_2 Photocatalyst

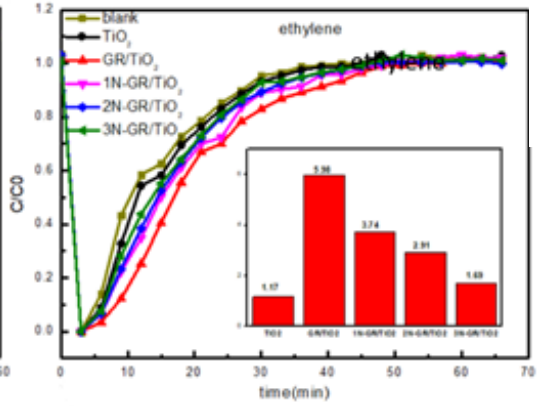


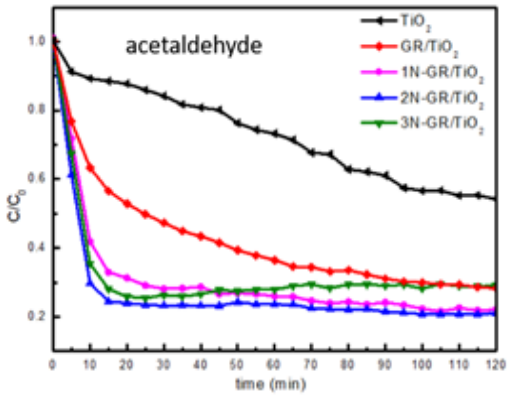


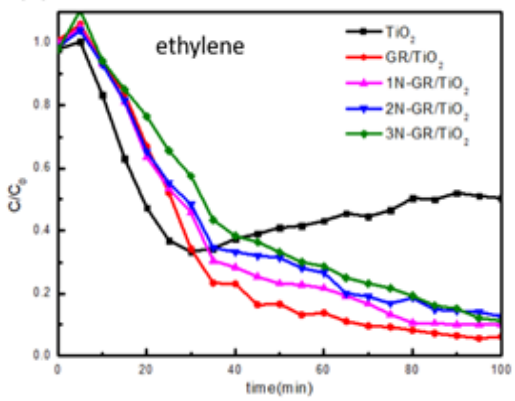


sample	TiO_2	GR/TiO_2	1N-GR/TiO_2	2N-GR/TiO_2	3N-GR/TiO_2
$S_{BET}(m^2/g)$	68.01	55.21	50.65	46.89	45.29









- Doping rGO with N could benifit the adsorption of acetaldehyde and the formation of $\cdot O_2^-$ radicals,
- N-rGO-TiO_2 Photocatalyst is more suitable for the ellimination of acetaldehyde,
- The interactions with photocatalysts are different for pollutants with different structures

Unpublished results

Since 1928

3. Conclusion

Conclusion

- Highly efficient carbon nanostructure-TiO_2 composite photocatalyst for the ellimination of gaseous pollutants
- The adsorption and radical-reaction process could be promoted through optimizing the surface of photocatalysts
- The selective adsorption and degradation of target VOCs could be achieved by adjusting the surface structures and surface functional groups of photocatalysts

Future work

- Understand the degradation process of organic molecules
- The selective adsorption and degradation of target VOCs
- Provide effective and stable photocatalysts for the persistant ellimination of VOCs to inhibite the formation of SOA

Thanks for my group members, thanks for the financial support from International Partnership Program of CAS with Prof. David Y. H. Pui and NSFC-DFG Bilateral organization program (51761135107) with Dr. Segets Doris.

Thank you for your attention!