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CNT-TiO₂ Composites for Photocatalytic Oxidation of Atmospheric Pollutants

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CNT-TiO₂ Composites for Photocatalytic Oxidation of Atmospheric Pollutants

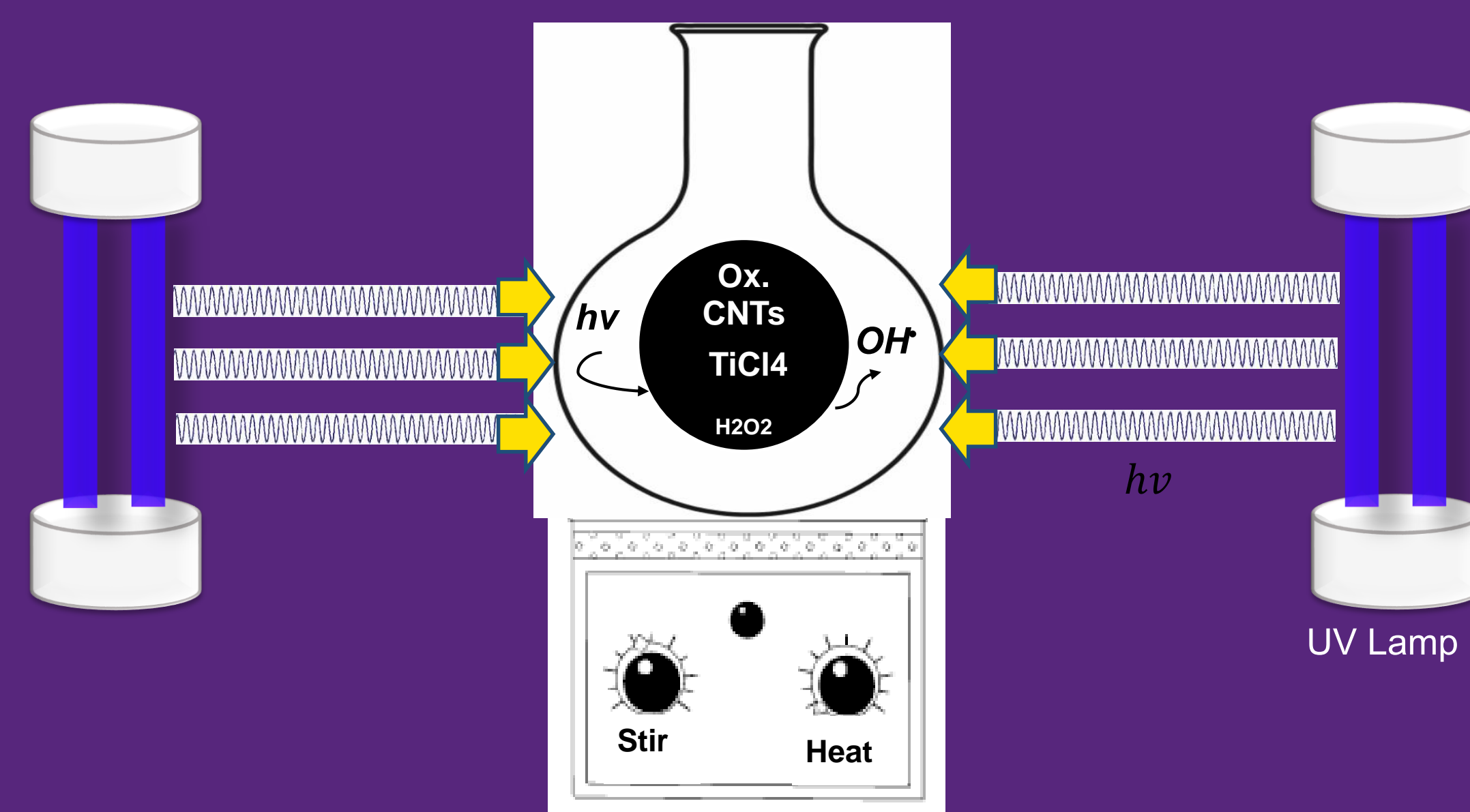
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Abstract

The design of catalysts for growth of carbon nanotubes is studied to develop recipes and mechanisms for controlled and scalable growth of carbon nanotubes (CNTs). The objective of the study is to tune the photocatalytic properties of titanium dioxide (TiO₂) by coupling to multiwalled carbon nanotubes (MWNTs). Multiwalled CNTs have been shown to act as an electron sink when coupled with TiO₂, thereby inhibiting electron-hole recombination and enhancing photocatalytic degradation of environmental pollutants. A test using acetaldehyde confirmed our findings in the field, where the loading ratio of 99 wt% TiO₂ (1 wt% CNTs) has a high efficiency in acetaldehyde degradation due to increased surface area as a result of improved TiO₂ dispersion. Addition of CNTs, however, resulted in a reduction of acetaldehyde degradation rate.

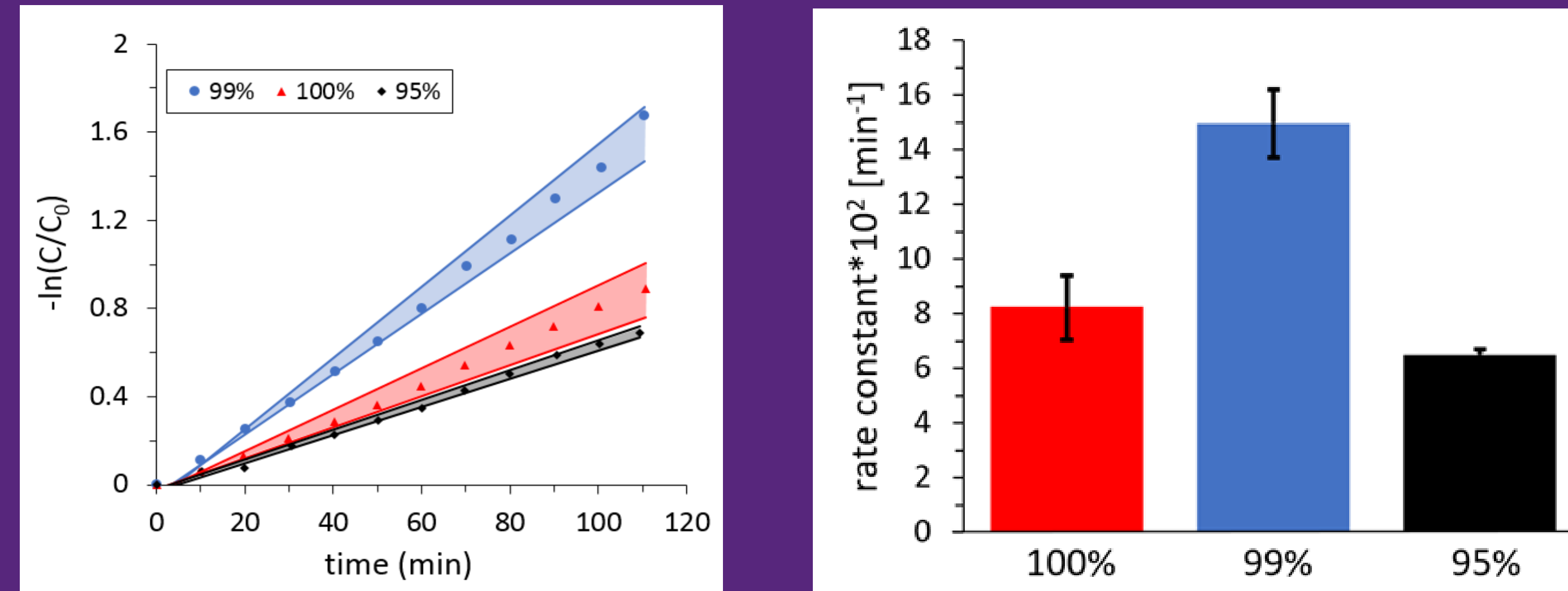
Experimental Method

Catalyst Synthesis



1. Oxidize CNTs by adding to H₂O₂ and exposing to UV illumination for 72 hours. Stir continuously
2. Filter, wash, and dry the oxidized CNTs
3. Add previously oxidized CNTs to 50 mL H₂O. Sonicate for 3 hours to disperse CNTs.
4. Cool dispersed CNT solution to 5°C. Add TiCl₄ dropwise to the solution.
5. Add NaOH to the solution to obtain a pH of 3-5
6. Transfer solution to autoclave. Heat to 150°C for 3 hours.
7. Dry catalyst under continuous airflow.
8. Bake catalyst powder at 250 °C for 3 hours.
9. Wash thoroughly using vacuum filtration.
10. Calcine samples at 450°C for 3 hours.

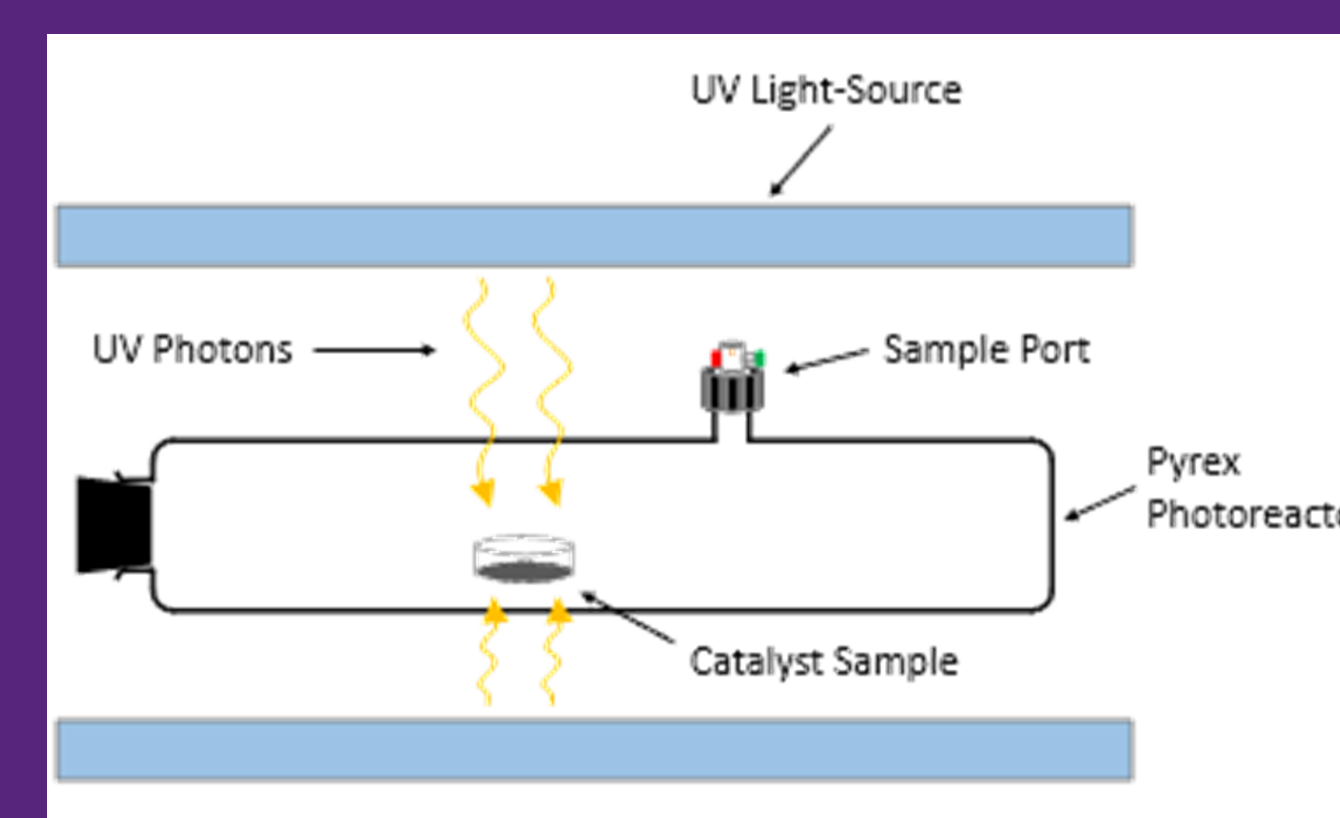
Results



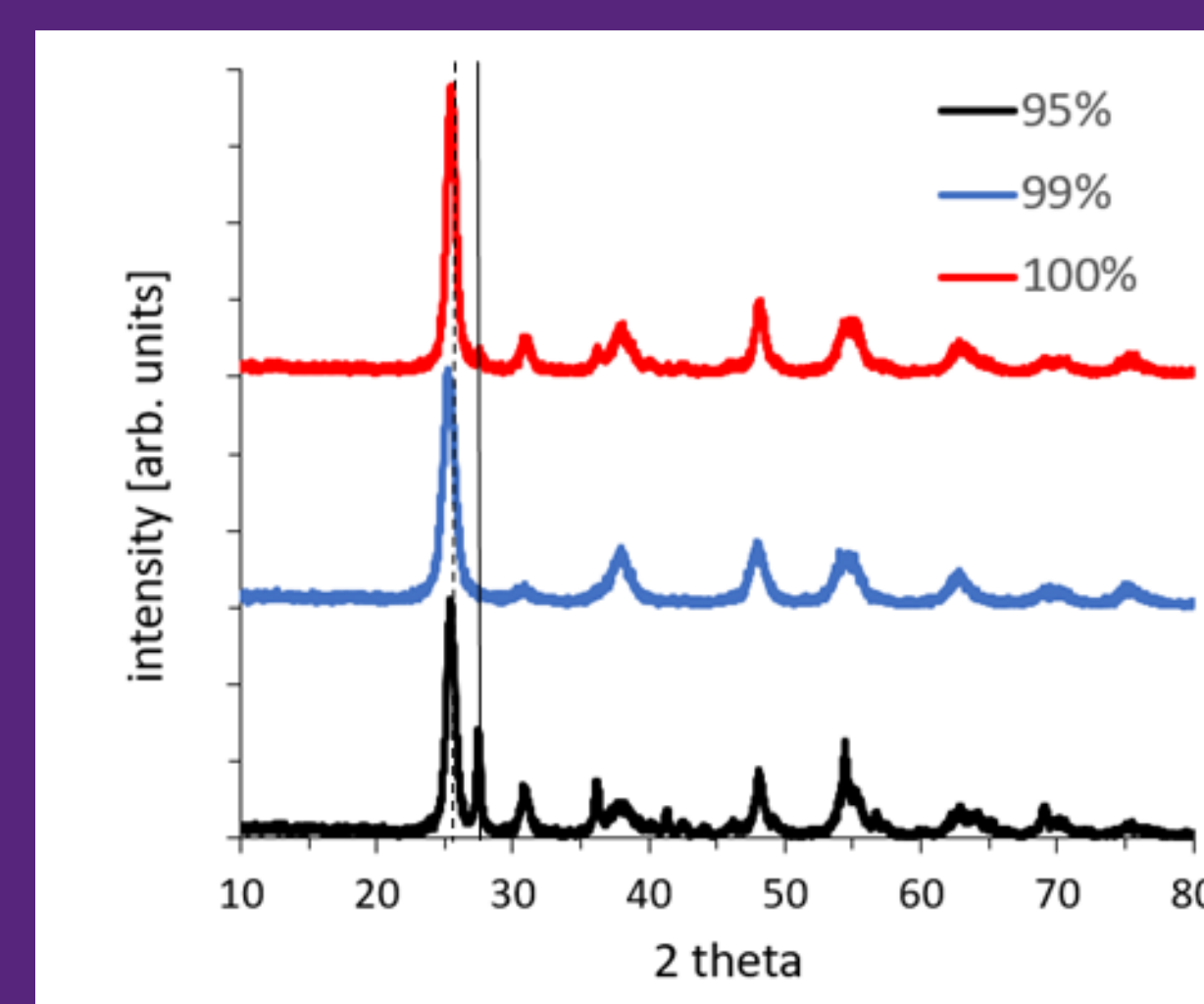
The 99 wt% TiO₂ photocatalyst exceeded the performance of the pure TiO₂ catalyst, indicating synergistic effects from the addition of 1 wt% CNTs.

Experimental Method

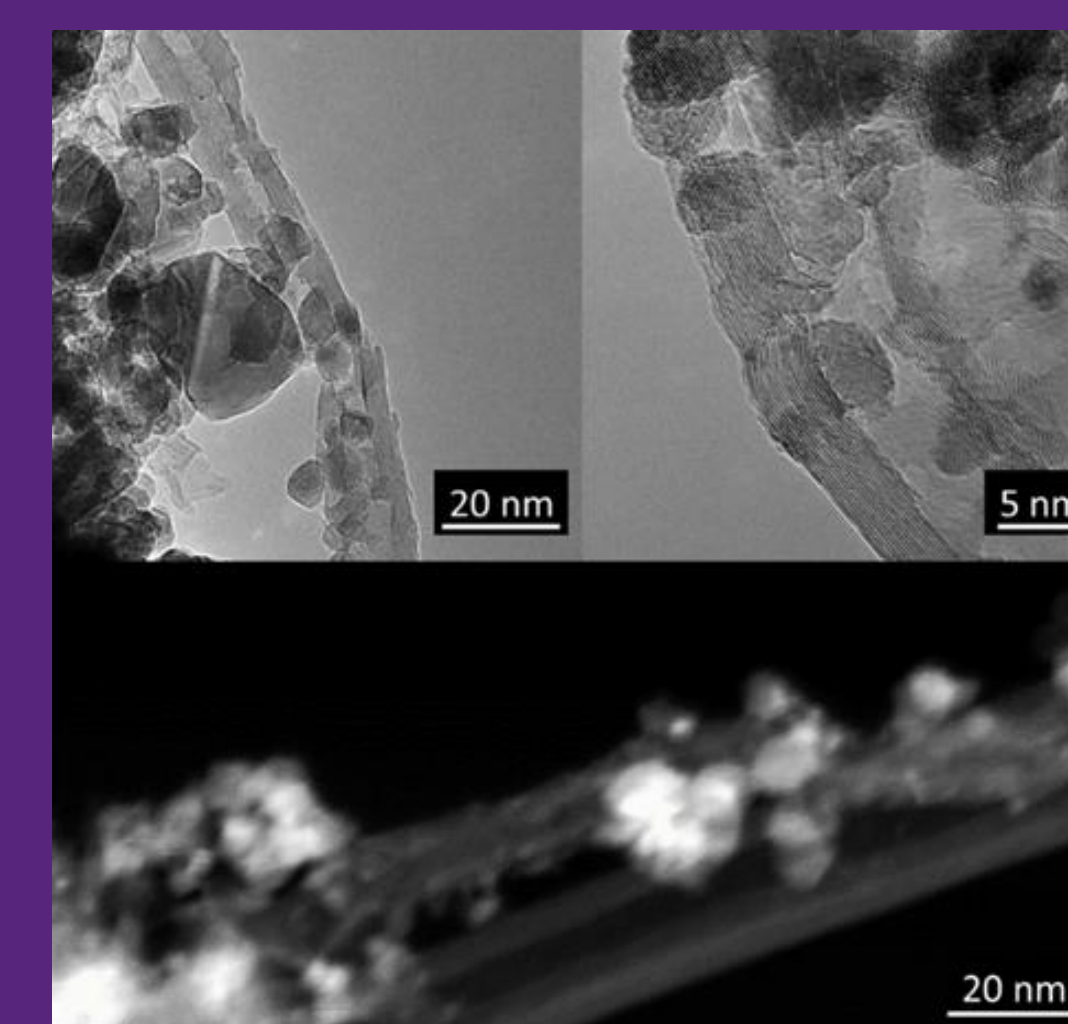
Photocatalytic Reactor and Testing



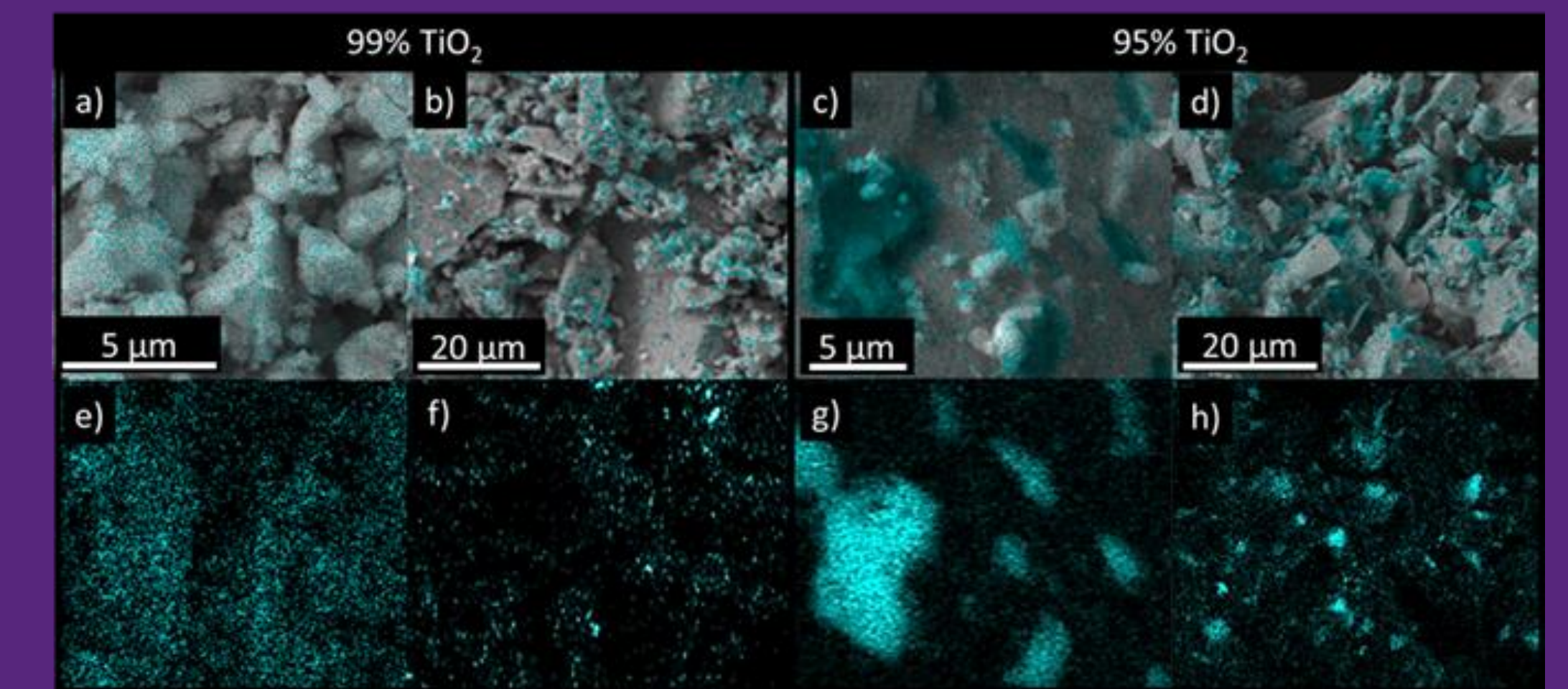
1. Load 0.100g sieved catalyst powder onto polystyrene sample dish.
2. Place in borosilicate batch reactor. Purge reactor of atmospheric gases.
3. Inject acetaldehyde vapor at 1000 ppmv. Leave to equilibrate in the dark for 90 minutes.
4. Initiate reaction with ultraviolet illumination system for 120 minutes.
5. Analyze samples with a gas chromatograph (GC) utilizing a flame ionization detector (FID) to measure acetaldehyde concentration over time.



The dashed line indicates the primary anatase (101) peak while the solid line indicates the primary rutile (110) peak.



TEM images of the 95 wt% catalyst, indicating intimate interaction between TiO₂ nanoparticles with the CNTs



SEM images with EDX overlaid, indicating carbon dispersion and agglomeration within the catalyst powders

Conclusions

- The addition of only 1% MWNTs resulted in nearly double the degradation rate of acetaldehyde vapor.
- The catalytic enhancements is a result of CNT presence has been attributed to morphological differences caused by CNTs present during TiO₂ particle nucleation.
- Further addition of CNTs at 5% resulted in hindered photocatalytic performance, attributed to CNT agglomerating during the hydrothermal process,

Future Work

- Modify catalyst precursor synthesis method to engineer CNT/TiO₂ heterojunctions.
- Degrade NO_x gas in a continuous flow reactor.
- Develop a coating to dip/spray coat onto substrates, showing a model of how the catalyst will work for environmental use.

References

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3. Zhang, B. et al., *Progress in Natural Science: Materials International* 2013, 23 (2), 164-169.

Acknowledgements

