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Synthesis of bismuth doped $CsSnBr_3$ nanocrystals for the photodegradation of industrial pollutant

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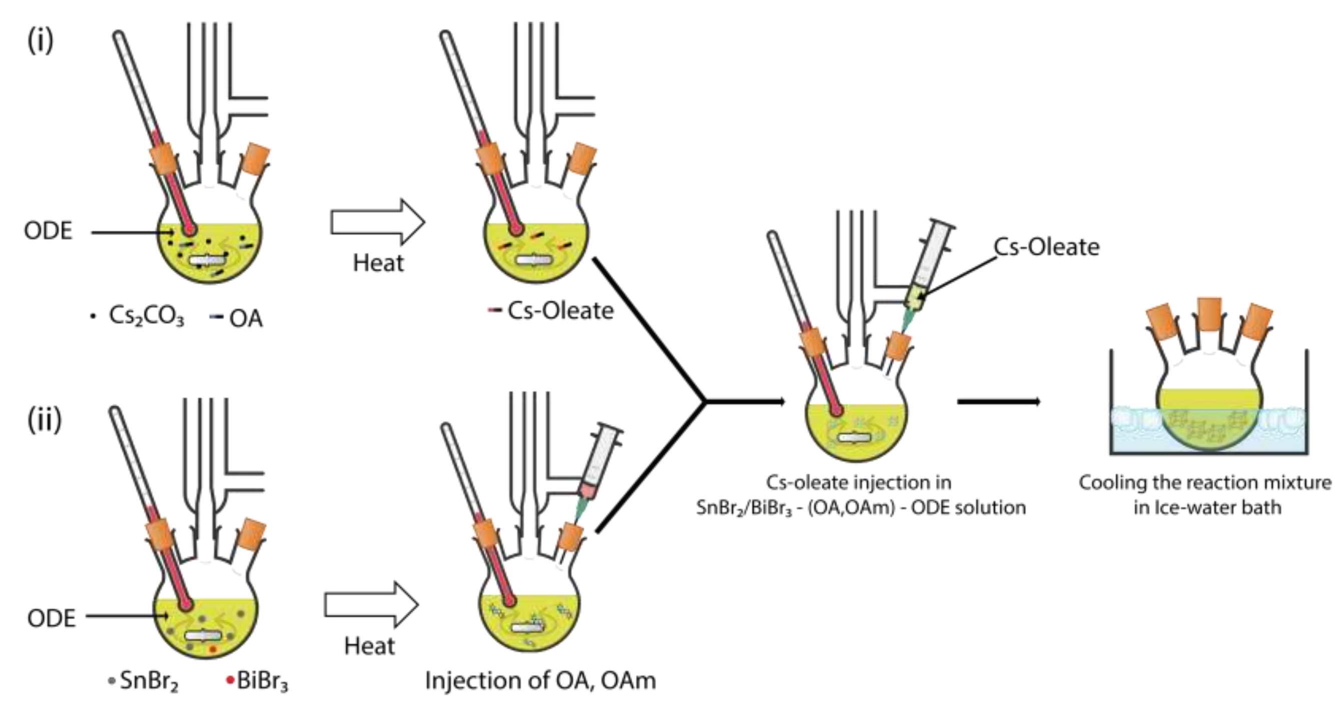
Background and Objectives

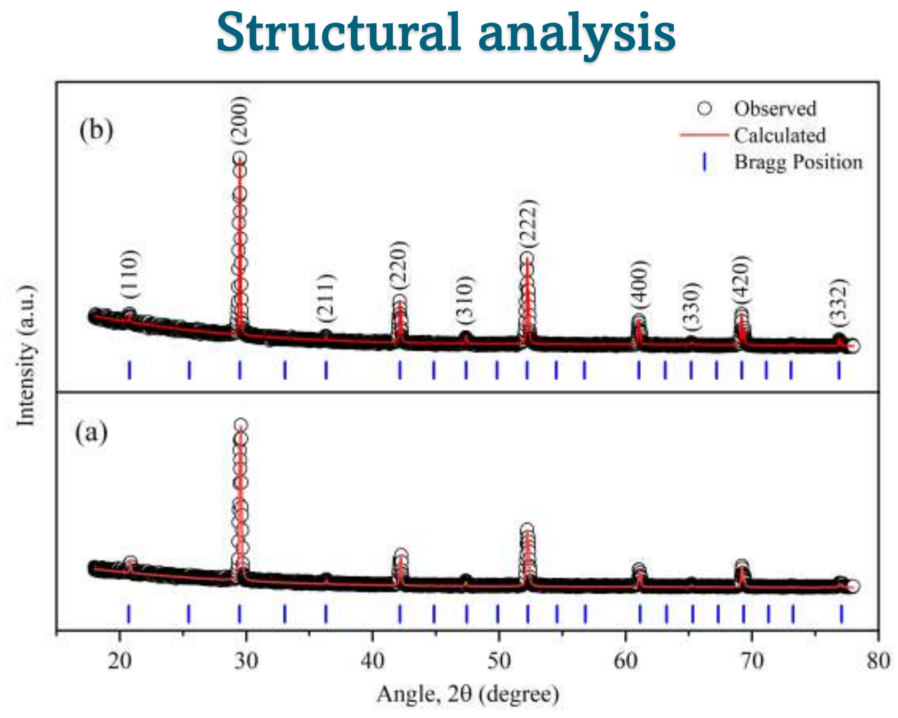
- To preserve the environment and public health, the treatment of wastewater containing numerous toxic pollutants has become imperative [1].
- Recently, metal halide perovskites are being widely investigated in removing the organic pollutants using solar irradiation [2].
- In this investigation, $CsSnBr_3$ and bismuth (Bi) doped $CsSnBr_3$ nanocrystals were prepared by the hot-injection method [3], and studied their structural, morphological, optical, as well as photocatalytic properties.

Synthesis steps



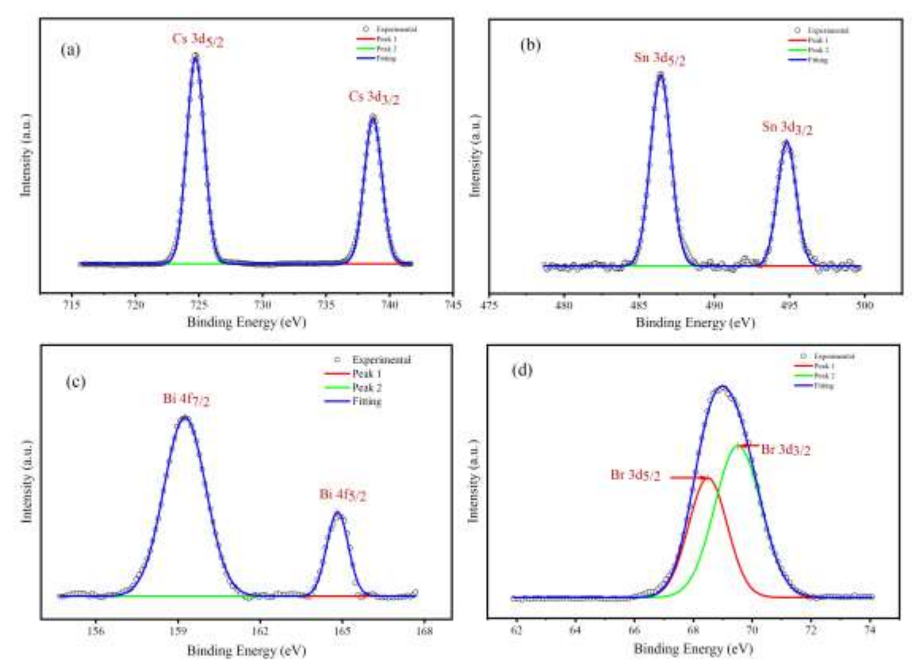
- Schematic diagram of synthesizing $CsSnBr_3$ nanocrystals in hot-injection technique

Structural analysis



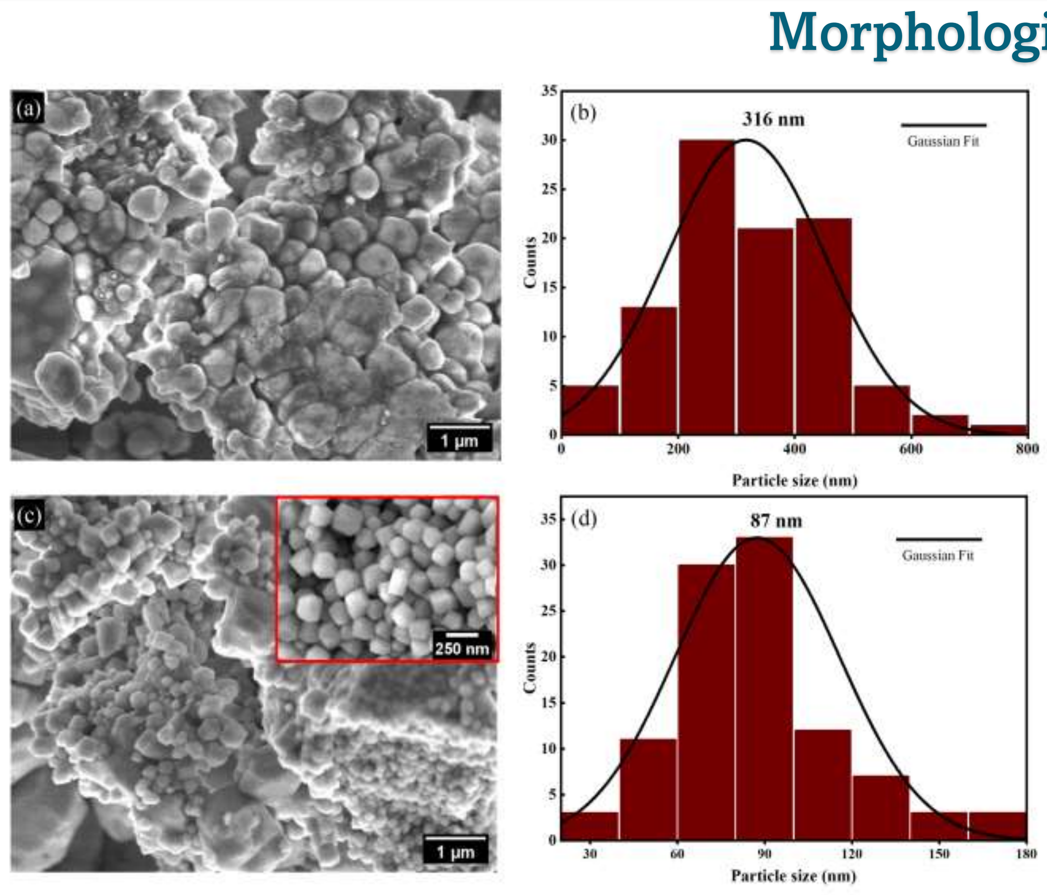
- Rietveld refined XRD pattern revealed the formation of cubic structured (a) pristine, and (b) Bi-doped $CsSnBr_3$ perovskites with space group *Pm-3m*

Chemical state analysis

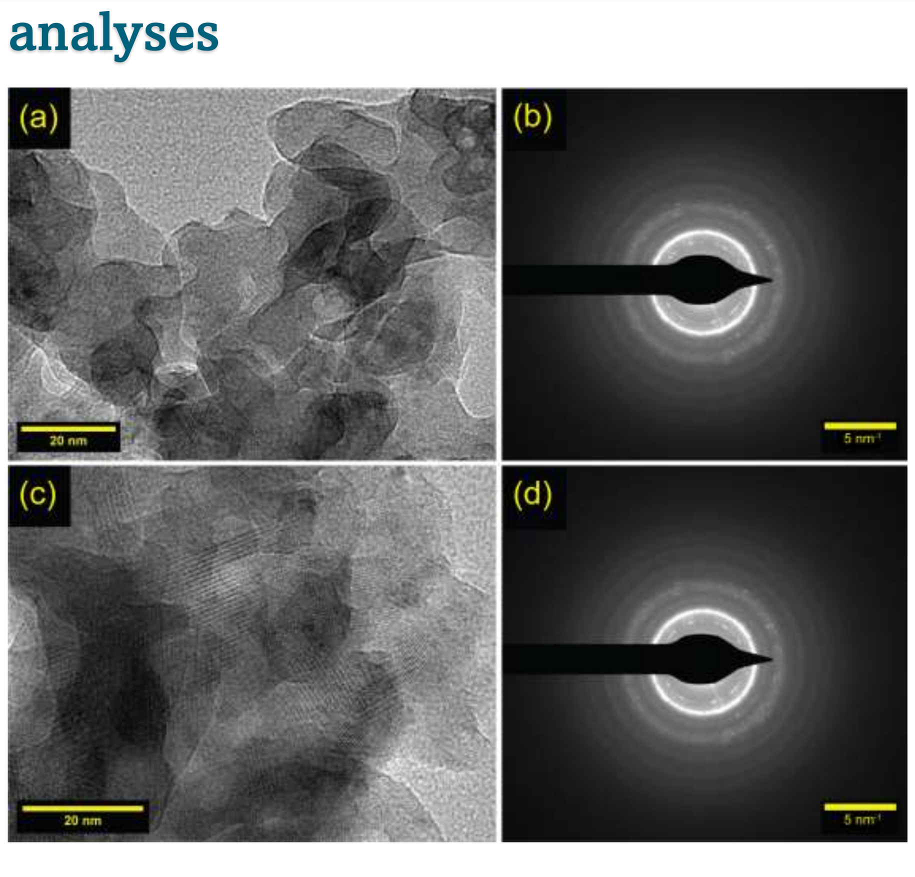


- XPS spectra validate the presence of Bi^{3+} in the doped sample.

Morphological analyses

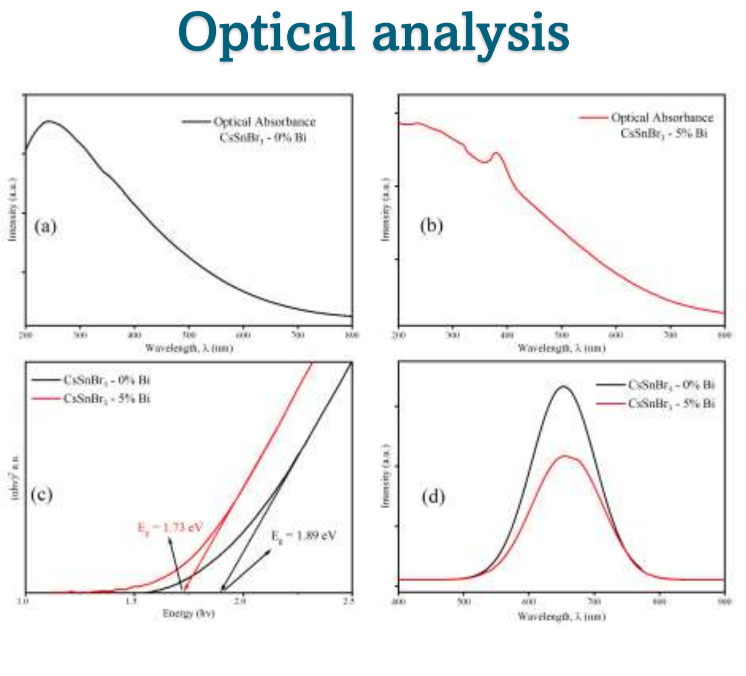


- FESEM imaging and particle size distribution revealed significantly improved morphology and reduced particle size due to Bi^{3+} doping.



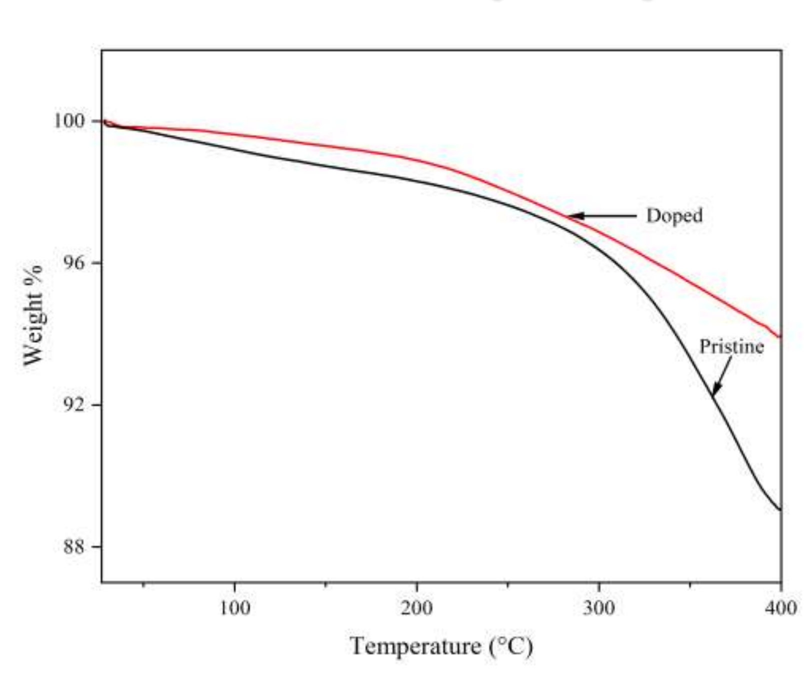
- HRTEM imaging depicts that the doped sample has higher crystallinity than the pristine one

Optical analysis



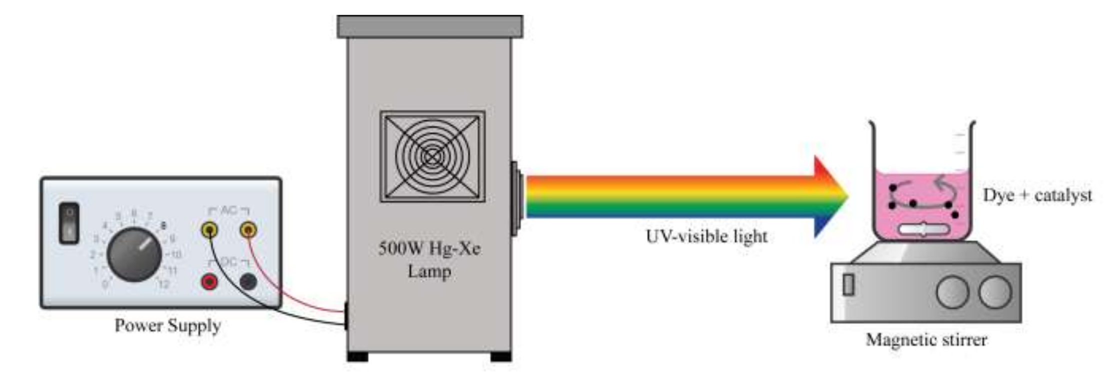
- The doped sample exhibits higher optical absorbance in the UV region and reduced band gap than the pristine one
- Suppression in photoluminescence spectra of the doped sample can be attributed to lower recombination rate of photo-generated charge carriers.

Thermal stability analysis



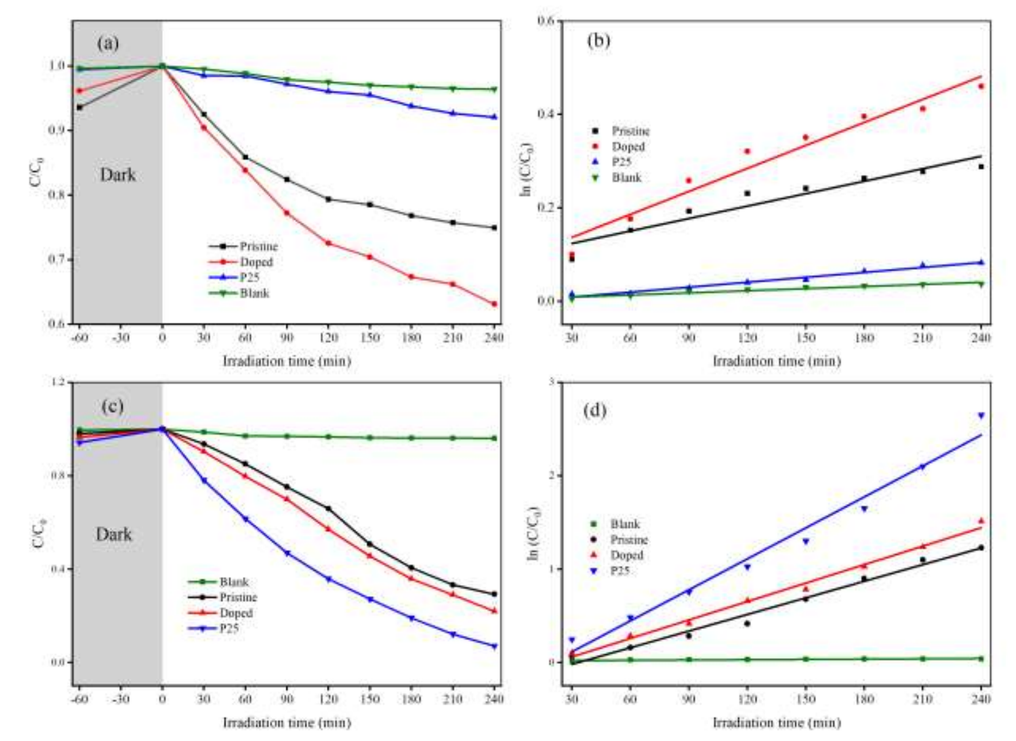
- Thermogravimetric analysis disseminated that the doping also improves the thermal stability of $CsSnBr_3$; above 300°C, the difference in the stability becomes more perspicuous.

Photocatalytic experiment



- Schematic diagram of a photocatalytic reactor setup for the organic dye degradation experiments

Photocatalytic dye degradation

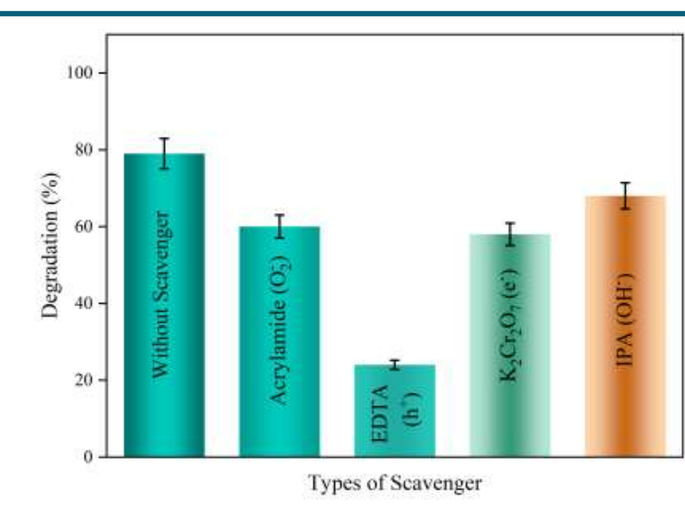


- The doped sample exhibited 17% and 11% higher dye degradation ability than the pristine one under visible and UV-visible spectrum, respectively.

Sample	Under visible spectrum		Under UV-vis spectrum	
	Efficiency	Rate Constant (min^{-1})	Efficiency	Rate Constant (min^{-1})
P25 Degussa	8%	0.00035	93%	0.01106
$CsSnBr_3$	25%	0.00089	68%	0.00597
$CsSn_{0.95}Bi_{0.05}Br_3$	42%	0.00164	79%	0.00658

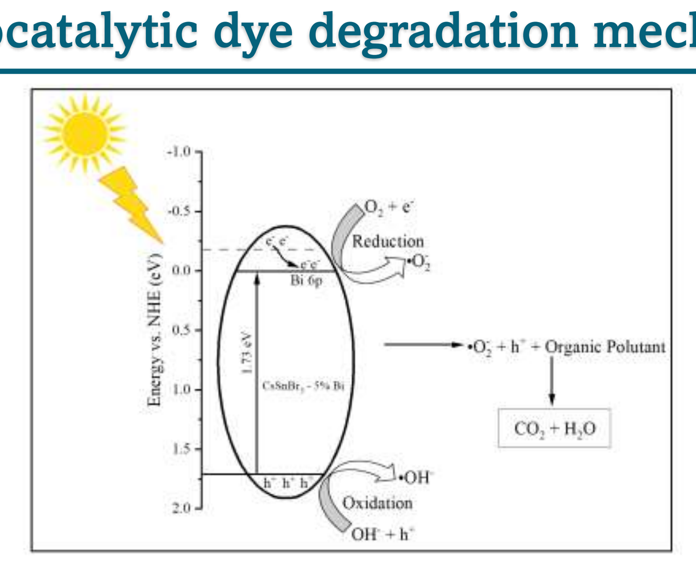
- Efficiency and degradation rate constant of as-prepared samples compared to commercially used photocatalyst, P25

Active species trapping experiment



- The active species trapping experiment asserted that the degradation mechanism was controlled primarily by holes.

Photocatalytic dye degradation mechanism



- Schematic diagram of RhB degradation mechanism based on the active species trapping experiment

Conclusions

- It is possible to incorporate 5 mol% bismuth in the B site of $CsSnBr_3$ perovskites without inducing secondary phase segregation.
- Thermal stability, morphology along with band-gap of metal halide perovskites can be tailored via B site doping.
- Bi-doped $CsSnBr_3$ nanoparticles demonstrated significantly high photocatalytic performance under visible irradiation than the P25 Degussa.

References

[1] Sharmin, Fahmida, *et al., Journal of Alloys and Compounds. 901, 16364, 2022* .
[2] Wang, Jin, *et al., Journal of Energy Chemistry. 54, 770 - 785, 2021.*
[3] Ali, M. S., *et al., Physical Chemistry Chemical Physics. 23, 22184-22198, 2021.*