Application of semiconducting nanoparticles supported on fibers for industrial dyes removal by photocatalysis

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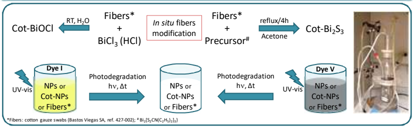
Background

Innovative and efficient solutions for water treatment are urging to overcome contamination problems. In that context, the removal of pollutants by adsorption and oxidation is of interest. Photochemical type methods of advanced oxidation processes (AOPs) based on semiconductor nanocatalysts (NCs), are promising for pollutants removal, such as industrial pollutants (including dyes), pesticides and other deleterious contaminants [1-3]. The use of supported NCs and sorbents allow to overcome problems of aggregation, activity loss, separation at the end of the process and release to the environment [2,4]. This work aimed to stably support semiconducting nanoparticles (NPs) onto fibers envisaging the preparation of photoactive hybrid materials for application in environmental remediation and facilitate catalyst recovery.

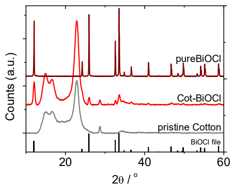
Experimental details

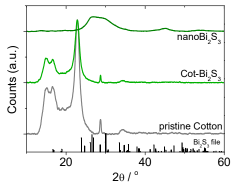


*Fibers: cotton gauze swabs (Bastos Viegas SA, ref. 427-002); # $Bi_2[S_2CN(C_2H_5)_2]_3$

Structural and morphological characterisation

XRD

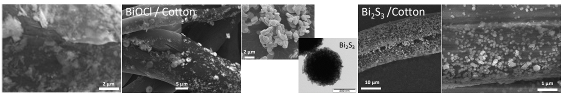




- Typical **BiOCl** diffraction peaks confirm the presence on the Cotton surface
- Predominance of the {001} facets on Cot-BiOCl
- Cellulose diffraction peaks preserved upon modification procedure
- **Bi_2S_3** - wide diffraction peak, agrees with the presence of extremely small crystallites

➜ **Bi_2S_3** not detected on the fibers surface

SEM and TEM



|BiOCl| = 14.3 mg g^{-1} of Cot-BiOCl

|Bi_2S_3| = 11.3 mg g^{-1} of Cot-Bi_2S_3

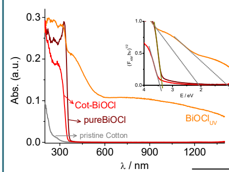
- Plate-like **BiOCl** particles and typical flower-like **Bi_2S_3** nanostructures distributed on the fibers surface

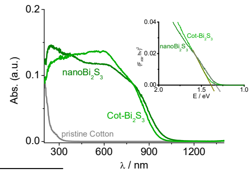
➜ Confirm successful Cotton surface modification

- Smaller **BiOCl** particles grown on the Cotton surface than in suspension
- Comparable amount of **BiOCl** and **Bi_2S_3** immobilized on the fibers surface

Optical characterisation

UV-vis diffuse reflectance





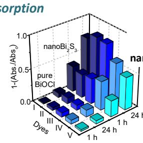
Sample	E_g / eV
pureBiOCl	3.37
nanoBi_2S_3	1.34
Cot-BiOCl	3.44
Cot-Bi_2S_3	1.39
$BiOCl_{UV}$	1.99/1.11

- Presence of **BiOCl** and **Bi_2S_3** on the fibers surface clearly observed on DRS spectrum
- **BiOCl** band edge in the UV and **Bi_2S_3** in the visible region ; **BiOCl** indirect band gap and **Bi_2S_3** direct band gap semiconductors
- Reversible self-sensitisation of BiOCl – **$BiOCl_{UV}$**:
  - Due to **Oxygen Vacancies**
  - **$BiOCl_{UV}$** absorbs in the whole UV + visible range

  ➜ extends the catalyst operation range

Photocatalytic activity

Adsorption

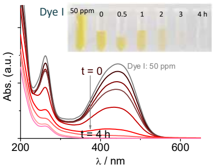


Dyes adsorption:

nanoBi_2S_3 > pureBiOCl

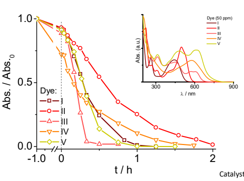
Fotodegradation

Cot-BiOCl - under visible radiation

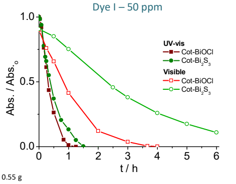


UV-vis spectroscopy

Cot-BiOCl under UV-vis radiation

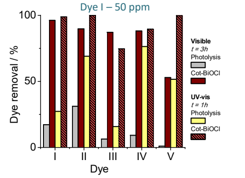


Dye I – 50 ppm



Catalyst: $m_{Cot-NPs}$ = 0.55 g

Dye I – 50 ppm



- **Cot-BiOCl** and **Cot-Bi_2S_3** enable faster dyes removal by photocatalysis than photolysis
- Although **Bi_2S_3** naturally absorbs in the whole visible and UV range, **Cot-BiOCl** performs better than **Cot-Bi_2S_3** under UV-vis and visible light

➜ **BiOCl** - better catalyst for the photocatalytic degradation of (*e.g.*) Dye I
  - efficient use of visible light and low recombination rate of electron-hole pairs
  - **OVs** introduce new energy levels in the forbidden band of the semiconductor

- Excellent performance of **Cot-BiOCl** for Dyes removal under visible light after 3 h exposure as compared with 1 h of UV-vis irradiation

References

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Conclusions

✓ Cotton supported catalysts have been successfully used for removal of industrial dye pollutants

✓ High ability to remove industrial dyes by adsorption (Bi_2S_3) and photodegradation (BiOCl)

✓ Successful attachment of the particles to the cotton surface ➜ nanocatalysts swiftly recovered after utilisation

❖ Promising and suitable approach for future wastewater treatment technologies to be applied for pollutants removal by combined adsorption/photodegradation methodologies with advantage on catalyst recovery

Acknowledgements

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