Fibers modified with semiconductor nanoparticles for environmental remediation and sensing

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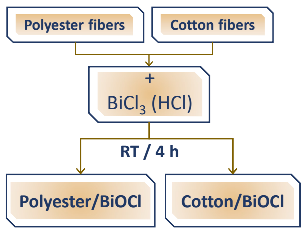
Introduction

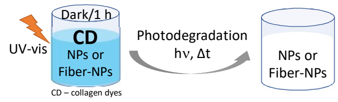
The modification of fibers has been widely explored towards the development of materials with specific and advantageous properties. This takes advantage from the possibility of imparting the properties of the NPs (or molecules) to the fibers, resulting in the preparation of a novel composite or hybrid material. Successful examples are the attachment of Ag, TiO_2 or BiOCl NPs to textile fibers for antibacterial, UV protection, self-cleaning and photocatalytic purposes, and the coating of fabrics with a hydrophobic layer (molecules or polymers) for water repellency and stain free fabrics. [1-4] In this work, several approaches for fibers modification are exploited towards the preparation of materials displaying photocatalytic and radiation sensing/protection responses.

Experimental details

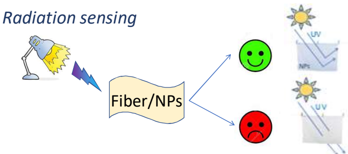
In situ fibers modification



Dye removal

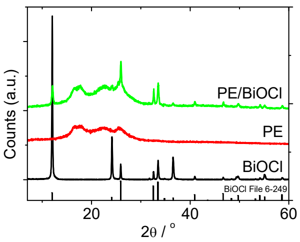


Radiation sensing

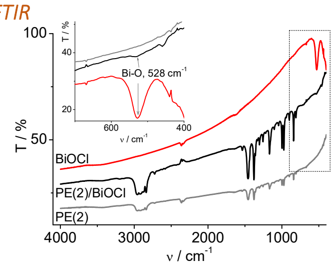


Polyester-BiOCl: characterization

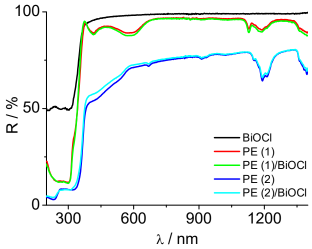
XRD



FTIR

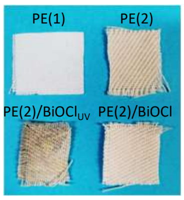


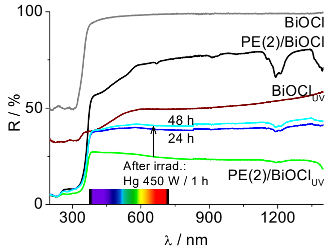
DRS



- BiOCl NPs:
  - crystalline, showing typical BiOCl diffraction peaks
  - clearly detected on the PE surface by XRD and FTIR
- PE(1) ≠ PE(2)
- BiOCl and PE absorbs in the UV
  - DRS did not allow the NPs detection

Optical response





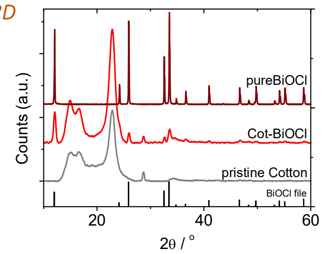
Sample	Conditions	After irradiation*	% recovery @ 650 nm 24 h	48 h
Hg 450W / 1h	Wet	-48.8	14.3	16.2
Xe-Hg 300W / 4h	Wet	-41.8	0.8	3.9
	Dry	-36.8	2.4	1.6
Xe-Hg 300W / 4h #	Wet	-31.7	1.8	3.8
Sun	Wet	-43.1	6.8	6.1
	Dry	-32.7	5.1	6.9

* compared with as prepared PE(2)/BiOCl; # with glass filter

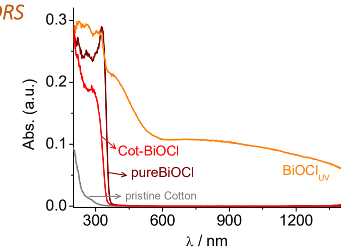
- Self-sensibilisation of BiOCl under light irradiation
  - Optical response in wet samples:
    - Hg 450 W > Xe-Hg 300 W ≈ Sun > Xe-Hg 300 W (w/ filter)
    - Faster recovery for Hg 450 W irradiated wet samples

Cotton-BiOCl: characterisation

XRD



DRS

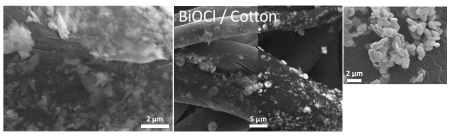


- Typical **BiOCl** diffraction peaks confirms its presence on the Cotton surface
- Predominance of {001} facets on Cot-BiOCl

- **BiOCl** band edge in the UV
- **BiOCl** indirect band gap semiconductor

Sample	E_g / eV
pureBiOCl	3.37
Cot-BiOCl	3.44
$BiOCl_{UV}$	1.99

SEM



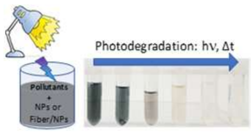
|BiOCl|= 14.3 mg g^{-1} of Cot-BiOCl

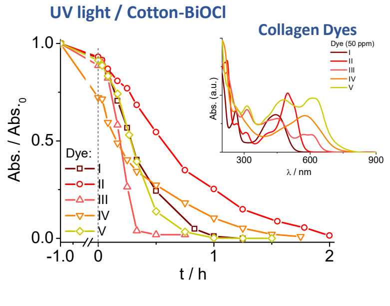
- Plate-like **BiOCl** particles distributed on the fibers surface
  - ➡ Confirms successful Cotton surface modification
- Smaller **BiOCl** particles grown on the Cotton surface than in suspension

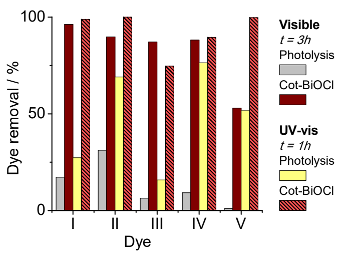
- Reversible self-sensitisation of BiOCl – $\mathbf{BiOCl_{UV}}$:
  - Due to **Oxygen Vacancies**
  - $\mathbf{BiOCl_{UV}}$ absorbs in the whole UV + visible range
  - ➡ extends the catalyst operation range

Pollutants removal

Photodegradation under UV-vis and visible radiation







- **Cot-BiOCl** - excellent catalyst for the degradation of dyes
  - ✓ fast dyes removal by photocatalysis
  - ✓ 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

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FCT Fundação para a Ciência e a Tecnologia

Conclusions

Polyester and cotton fibers were successfully modified with **BiOCl NPs** as shown by XRD, DRS, SEM and FTIR. Those NPs are crystalline and can be self-sensitised by light irradiation due to oxygen vacancies formation.

PE-BiOCl samples show that the degree of sensitisation and the reversibility of the process depends on the conditions (*e.g.* wet/dry) and radiation source (energy). The results are encouraging towards radiation detection systems.

Cot-BiOCl composites have been successfully used for the removal of industrial dye pollutants by photodegradation and the nanocatalysts were swiftly recovered after utilisation.

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

References:
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