Sustainable Semiconductors: Bismuth Chalcohalides for Environmental and Radiation Applications

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Research
Nanomaterials and radiation group
Radiochemistry Area

Synthesis of semiconductor nanoparticles:
Applications

- Nanomedicine (cancer treatment)
- Radiation detectors
- Water treatment by photocatalysis

Research

Synthesis of semiconductor nanoparticles:
Applications
Ecotoxicity

- Nanomedicine (cancer treatment)
- **Radiation detectors**
- **Water treatment by photocatalysis**

The transition to sustainable electronics requires the development of novel materials with high efficiency, low environmental impact, and optimized resource utilization.

Bismuth-based semiconductors

Bismuth-based semiconductors

BiSI

$Bi_{19}S_{27}I_3$

Bismuth-based semiconductors

BiSI

Promising candidate:

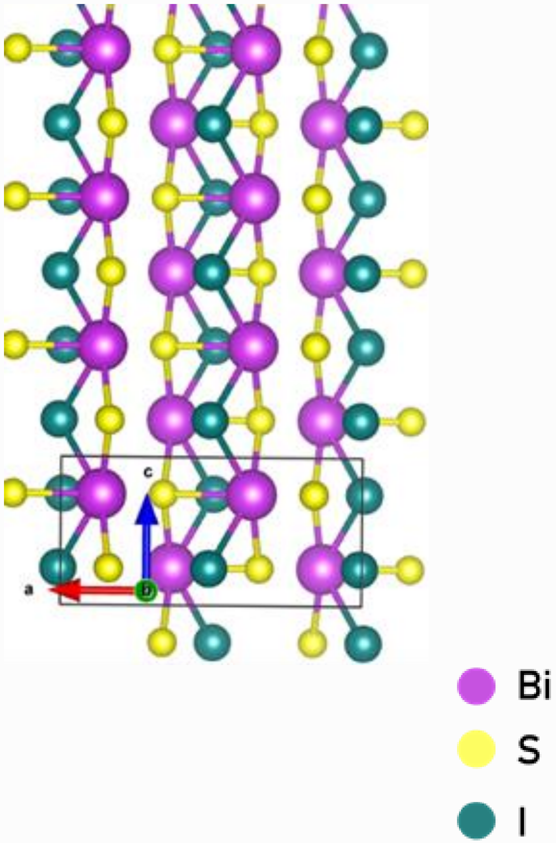
Photocatalysis
Photodetection
Hard radiation detection
Supercapacitors
Solar cells

Synthesis

Presents several challenges in terms of:
Phase purity
Environmentally friendly methods

BiSI

Is gaining attention due to:
Anisotropic optoelectronic properties
Comprising relatively abundant and non-toxic elements



Bismuth-based semiconductors

$Bi_{19}S_{27}I_3$

Promising candidate:

Photocatalysis
Photodetection
Hard radiation detection
Supercapacitors
Solar cells

Synthesis

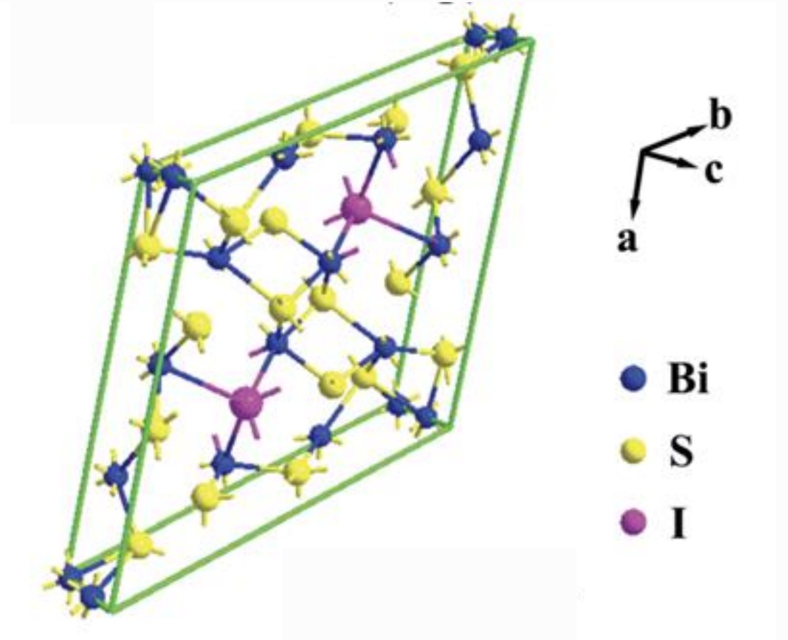
Synthesis and properties are not thoroughly studied.

$Bi_{19}S_{27}I_3$

Is gaining attention due to:
Anisotropic optoelectronic properties
Comprising relatively abundant and non-toxic elements

Stoichiometry

More than one way of writing it:
$Bi(Bi_2S_3)_9I_3)_{0.666715}$ or $Bi_{13}S_{18}I_2$

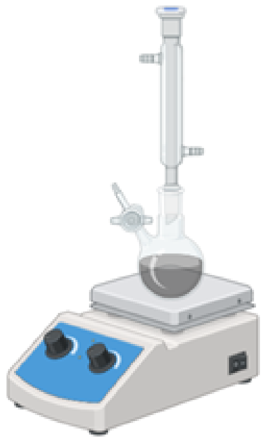


Synthesis – BiSI

Pure and a composite

Mild conditions and green solvents

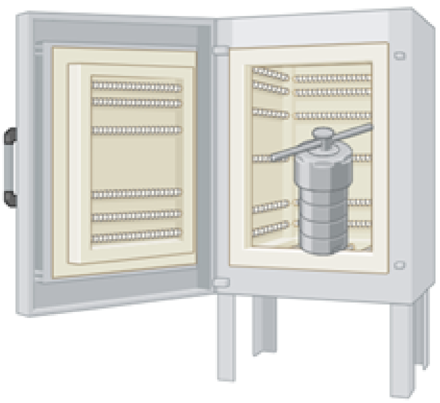
BiSI		BiSI/C
SOLUTION SYNTHESIS		SOLVOTHERMAL SYNTHESIS



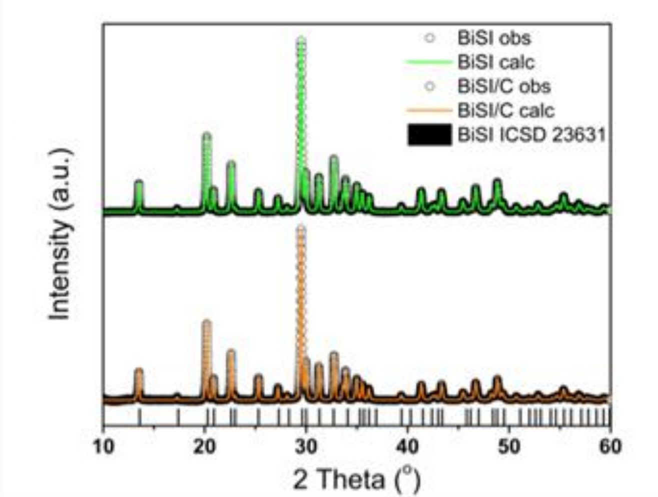
Medium
Mono ethylene glycol
(MEG)

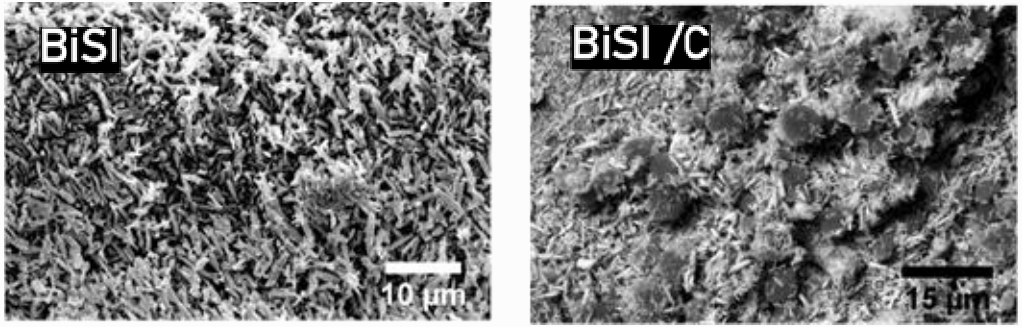
Precursors
Bi_2S_3 , I_2

Temperature
180°C

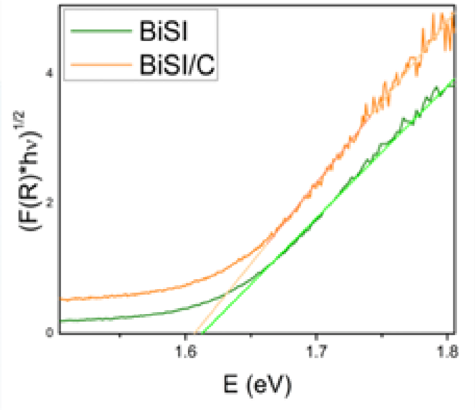


Characterization



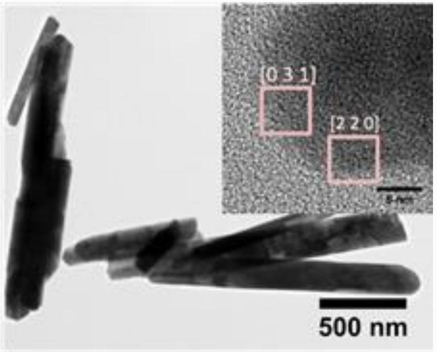


SEM images show BiSI nanorods in both cases, but also carbon round particles in the solvothermal synthesis.



E_gBiSI: 1.61 eV
E_gBiSI/C: 1.61 eV

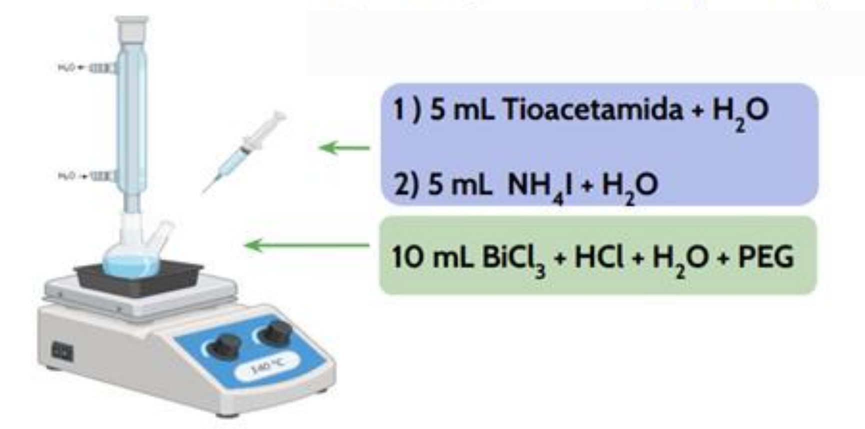
BiSI and BiSI/C have the same indirect band gap



TEM images of nanorods found in samples from BiSI and BiSI/C. HR-TEM shows planes corresponding to BiSI.

Synthesis – $Bi_{19}S_{27}I_3$

Green method



Hot injection method

Water as solvent

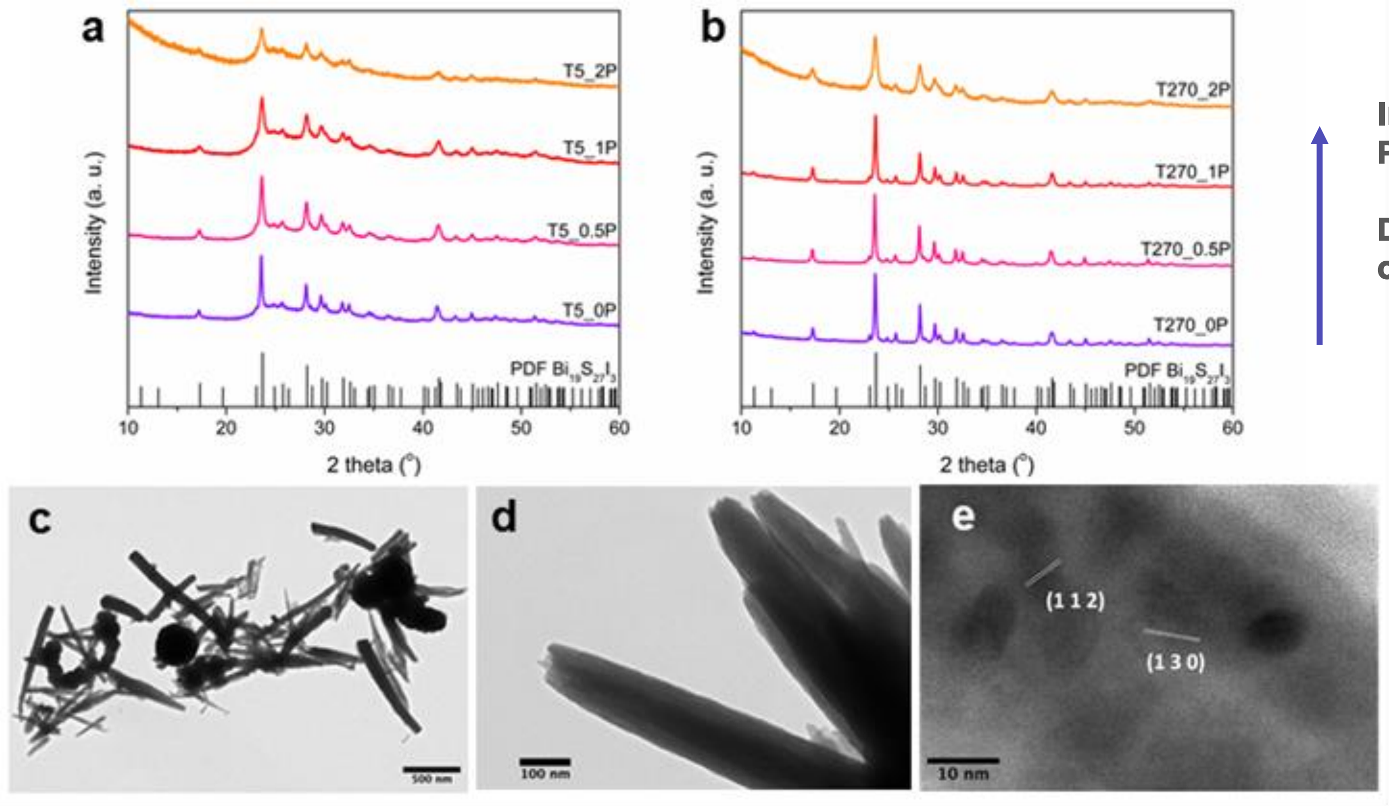
PEG as capping agent

Variations: time and PEG amount

Results

XRD 5 min

XRD 270 min



Increases PEG amount

Decreases cristallinity

Two morphologies: nanorolls and rounded nanoparticles

Results

Journal of
Materials Chemistry C

ROYAL SOCIETY
OF CHEMISTRY

PAPER

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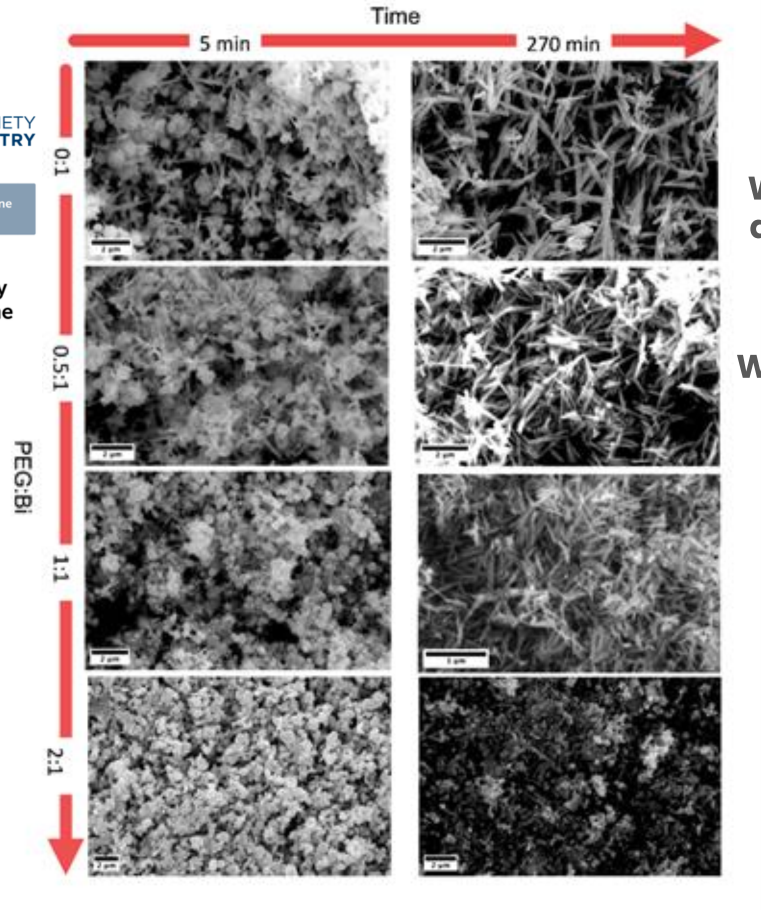
Cite this: DOI: 10.1039/d4tc01480d

Green solution synthesis of $Bi_{19}S_{27}I_3$ nanostructures – engineering their morphology through polyethylene glycol and their use in the photocatalytic reduction of Cr(VI)†

Maia Mombrú-Frutos,[a] Martina Viera,[ab] Carolina Grosso,[a] Mauricio Rodriguez Chialanza,[c] Laura Fornaro,[b] María Eugenia Pérez Barthaburu *[b] and Ivana Aguiar *[a]

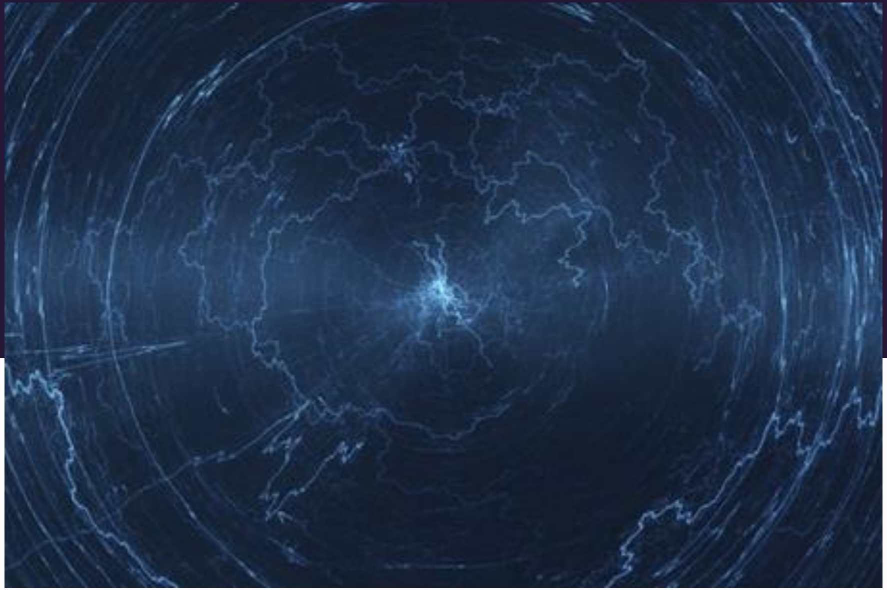


With time 5 min the samples are formed by nanorolls and round nanoparticles

With time 270 min the samples only have nanorolls

Round nanoparticles dissolve with time

Radiation detectors



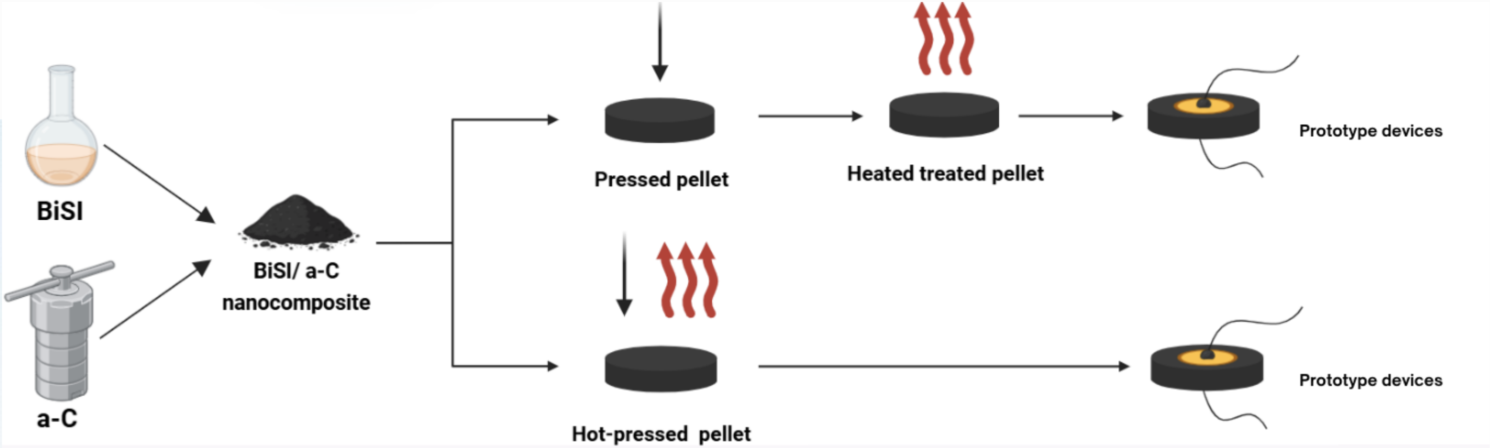
Radiation detection with pellets

Pellets fabrication – BiSI

U.PS4.28 - Effect of Thermal Treatment on the Structure and Morphology of BiSI Pellets for Radiation Detector Applications

Martina Viera , Maia Mombrú , Carlos Javier Pereyra, Ivana Aguiar

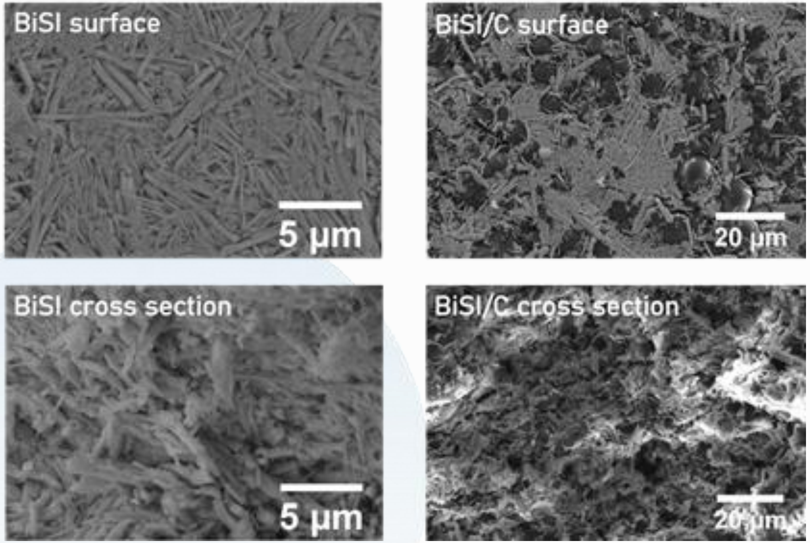
Tomorrow!

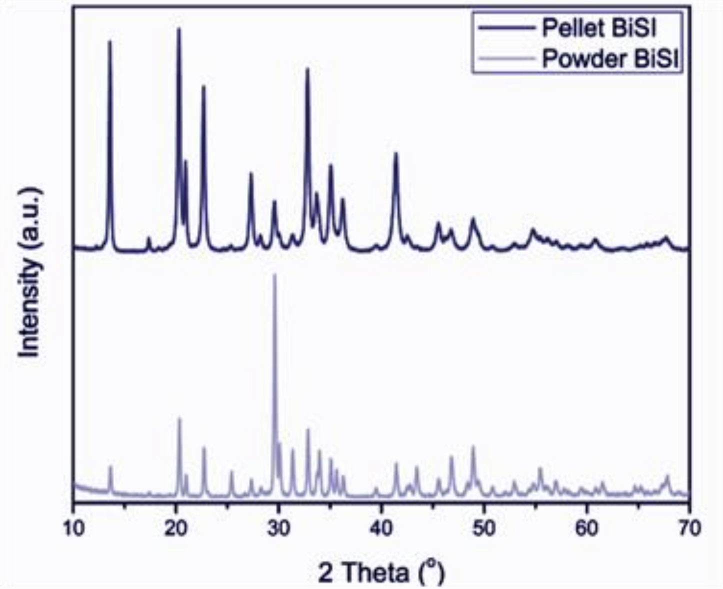


Radiation detection with pellets

Pellets fabrication – BiSI

COLD UNIAXIAL PRESS: 9 TON



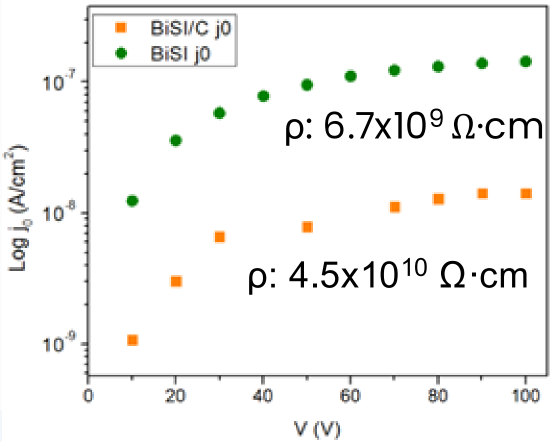


Increase in (*h k 0*) planes intensities show a slightly preferred orientation of rods parallel to the surface, and this is increased in the pure compound

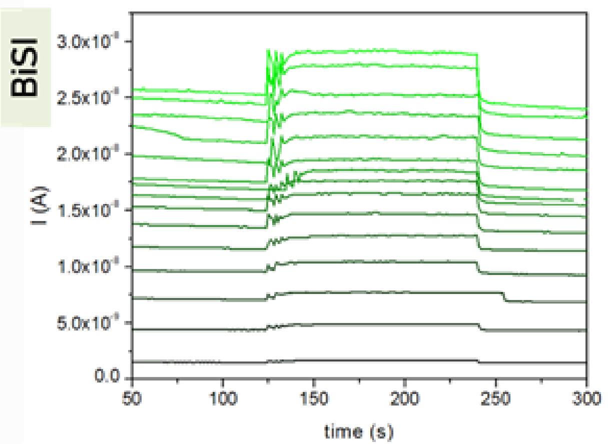
Radiation detection with pellets

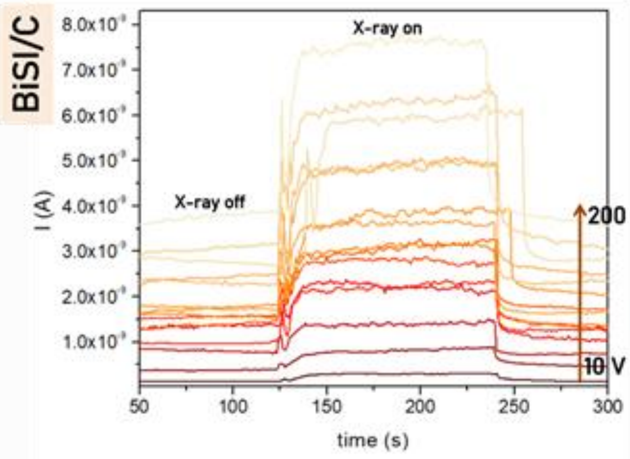
X-ray detection

Dark current density vs applied voltage



Response to X-rays (~20 mGy/s) with applied voltage

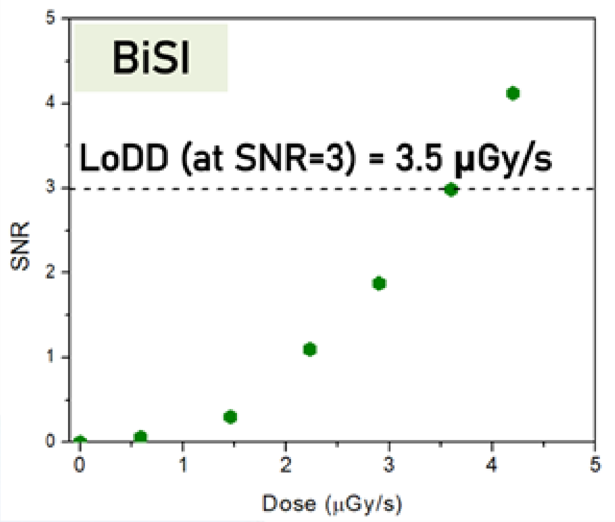


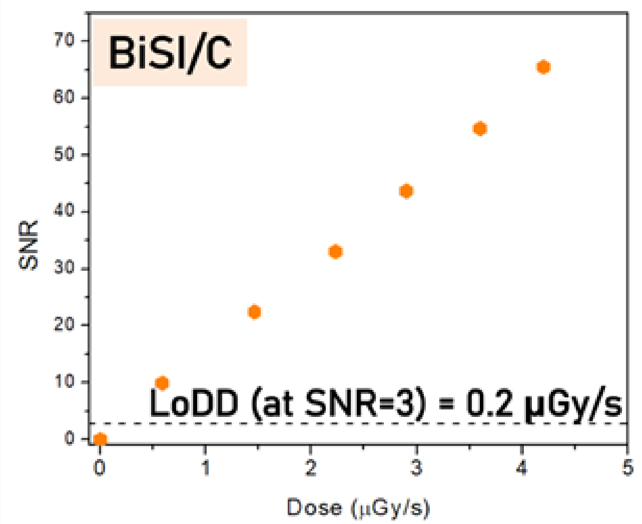


The higher resistivity of BiSI/C nanocomposite results in a lower background noise and a better response to radiation either for an increasing voltage bias or dose rate.

Radiation detection with pellets

X-ray detection



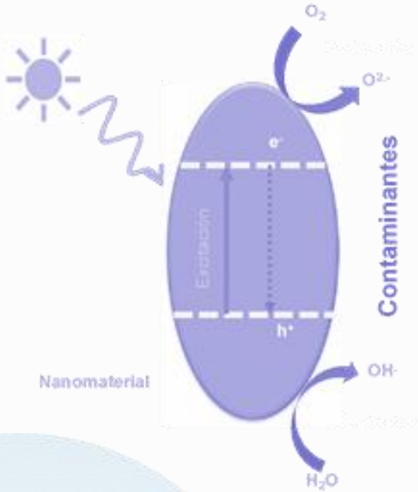


Carbon particles in the nanocomposite BiSI/C allow for a more robust device capable of detecting lower doses than pure BiSI

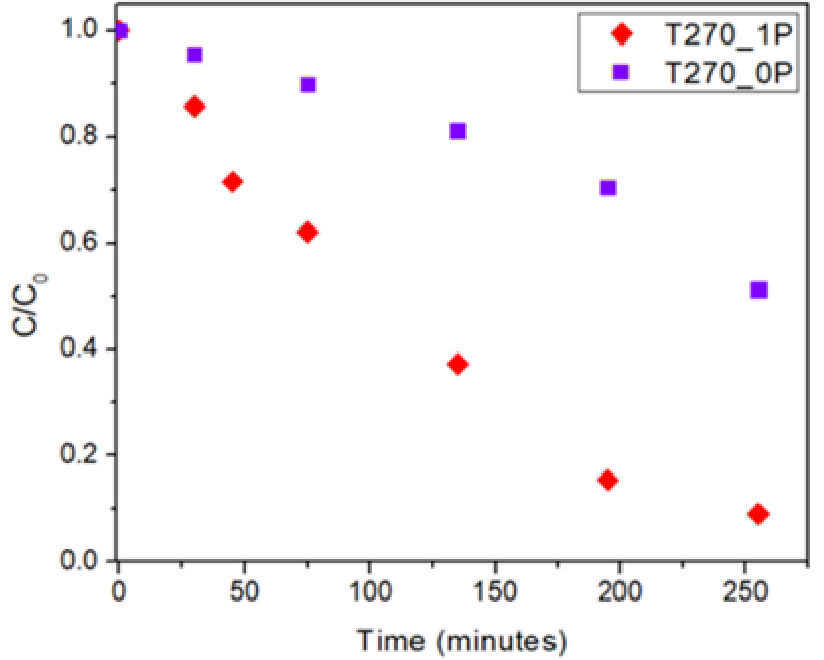
Photocatalysis

Results – $Bi_{19}S_{27}I_3$

Degradation of Cr(VI) by photocatalysis



Samples without and with PEG containing only nanorolls



Determination by the diphenylcarbazide method

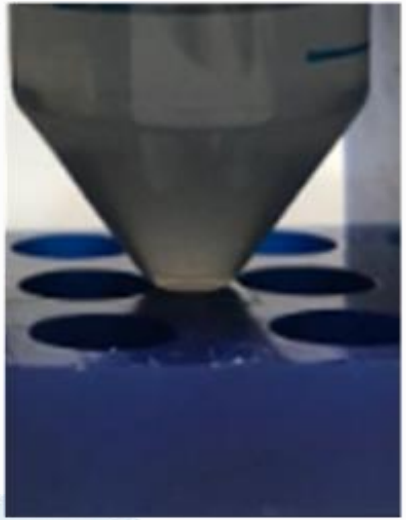
M. Mombrú et al, Green solution synthesis of Bi19S27I3 nanostructures - engineering morphology through polyethylene glycol and photocatalytic reduction of Cr (VI), Journal of Materials Chemistry C

After 255 min, sample T270_1P achieves 91% of degradation

Results

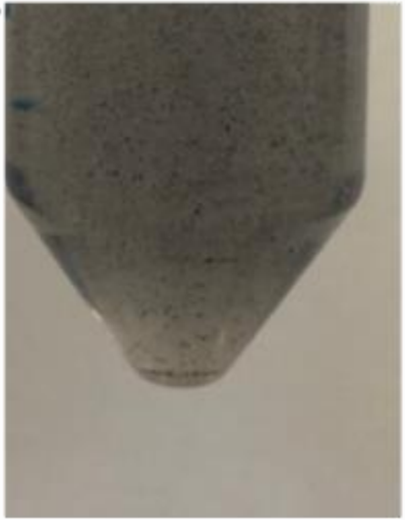
Degradation of Cr(VI) by photocatalysis

a



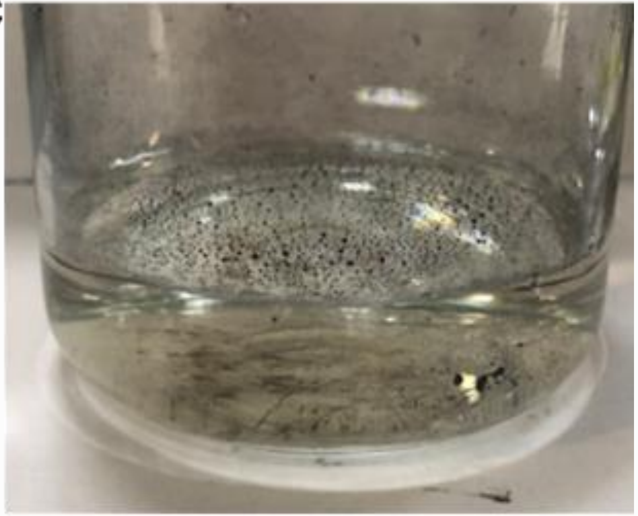
Sample T270_1P suspended in Cr(VI) aqueous solution

b



Sample T270_0P suspended in Cr(VI) aqueous solution

c



Sample T270_0P in Cr(VI) aqueous solution in the photocatalysis reactor.

PEG-capped nanorolls are better suspended in water

The PEG improves the stabilization of the nanorolls in an aqueous solution, more intimate exchange between the semiconductor nanostructures surface and the Cr(VI)

Conclusions
X-ray detectors

We present two simple methods for obtaining either pure BiSI phase nanorods or a BiSI-C nanocomposite.

Both materials detect low energy X-rays in a simple sandwich device configuration, but the nanocomposite has a better overall performance.

Conclusions Photocatalysis

Green synthesis approach for nanostructures of $Bi_{19}S_{27}I_3$.

We successfully controlled the morphology of the nanostructures by adding PEG as capping agent at different concentrations and varying the reaction time.

The incorporation of PEG enhanced the dispersion of the nanostructures in water, improving the efficiency of $Bi_{19}S_{27}I_3$ nanostructures as a photocatalyst for Cr(VI) reduction.

Conclusions

Our results support progress toward key Sustainable Development Goals (SDGs), including **SDG 6 (Clean Water and Sanitation)** through effective pollutant removal and **SDG 3 (Good Health and Well-being)** via advanced radiation detection for medical and environmental safety.

Our group

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Chemistry of Sustainable Materials

Thank you!

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