Effect of Thermal Treatment on the Structure and Morphology of BiSI Pellets for Radiation Detector Applications

Martina Viera[1], Maia Mombrú Frutos[1], Carlos Javier Pereyra[2], Ivana Aguiar[1]

[1] Área Radioquímica, Facultad de Química, Universidad de la República, Montevideo, Uruguay.
[2] Instituto de Física, Facultad de Ingeniería, Universidad de la República, Montevideo, Uruguay.

mviera@fq.edu.uy

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Introduction

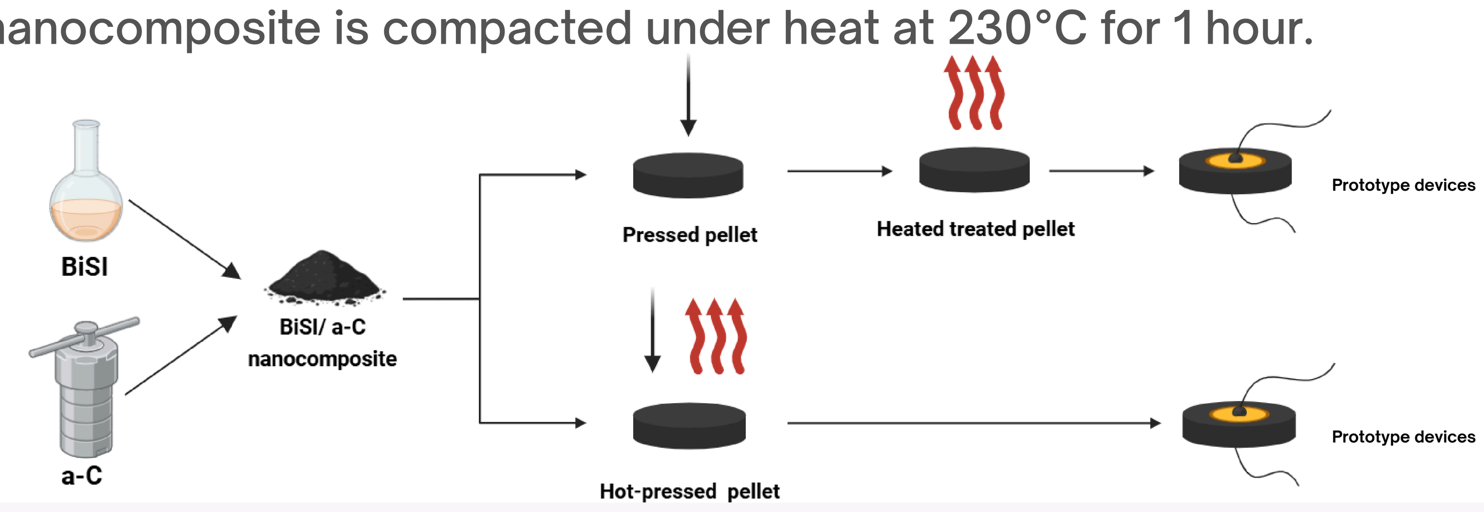
The development of accessible radiation detectors motivates the exploration of alternatives to challenging single-crystal growth.
This work focuses on fabricating detectors from pressed pellets of a bismuth sulfoiodide (BiSI)/amorphous carbon (a-C) nanocomposite.

The semiconductor BiSI is an ideal candidate due to its suitable band gap (1.6 eV) and high density (6.4 g cm^{-3}).

This study optimizes the fabrication process by investigating different BiSI-to-carbon ratios and thermal treatments, with the goal of producing functional prototypes for electrical characterization and application.

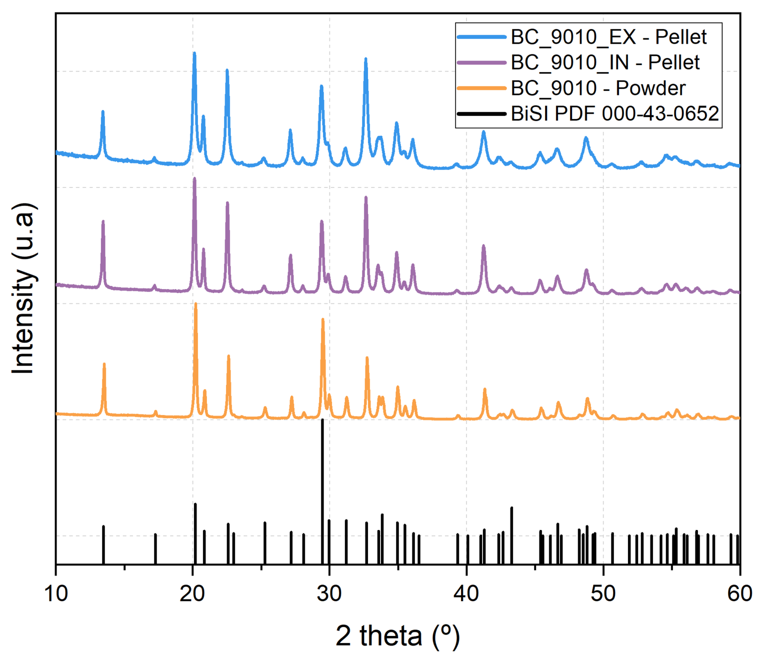
Experimental

- The starting materials were synthesized separately: BiSI was prepared using a solution-based route, while a-C was produced via a solvothermal method [2].
- Materials were mixed in known proportions to conform the nanocomposite.
- Method ***ex situ***:
  - Nanocomposite is pressed into a pellet at room temperature.
  - The pellet is subsequently annealed in a furnace at 230°C for 1 hour.
- Method ***in situ***:
  - The nanocomposite is compacted under heat at 230°C for 1 hour.



Results

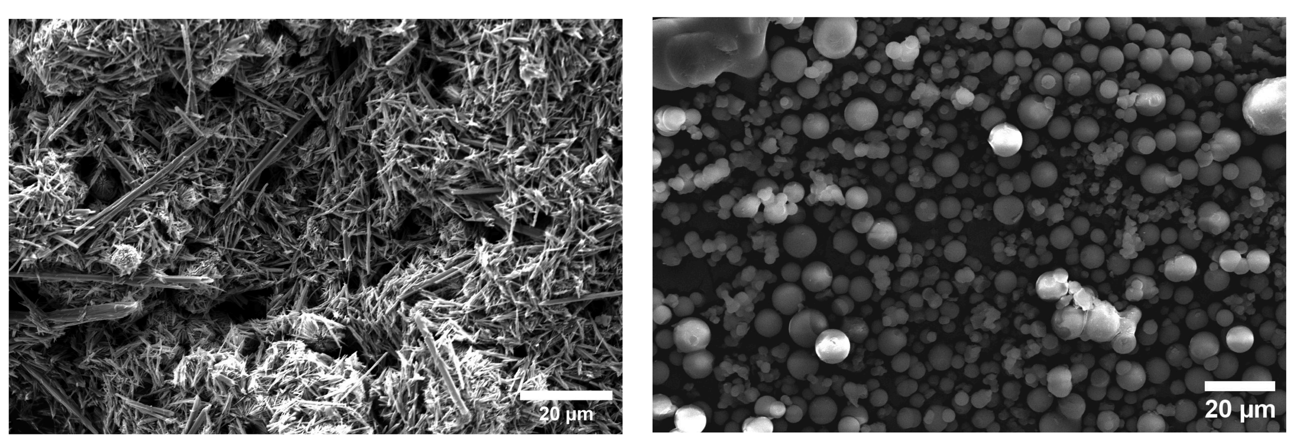
X-ray powder diffraction (XRD)



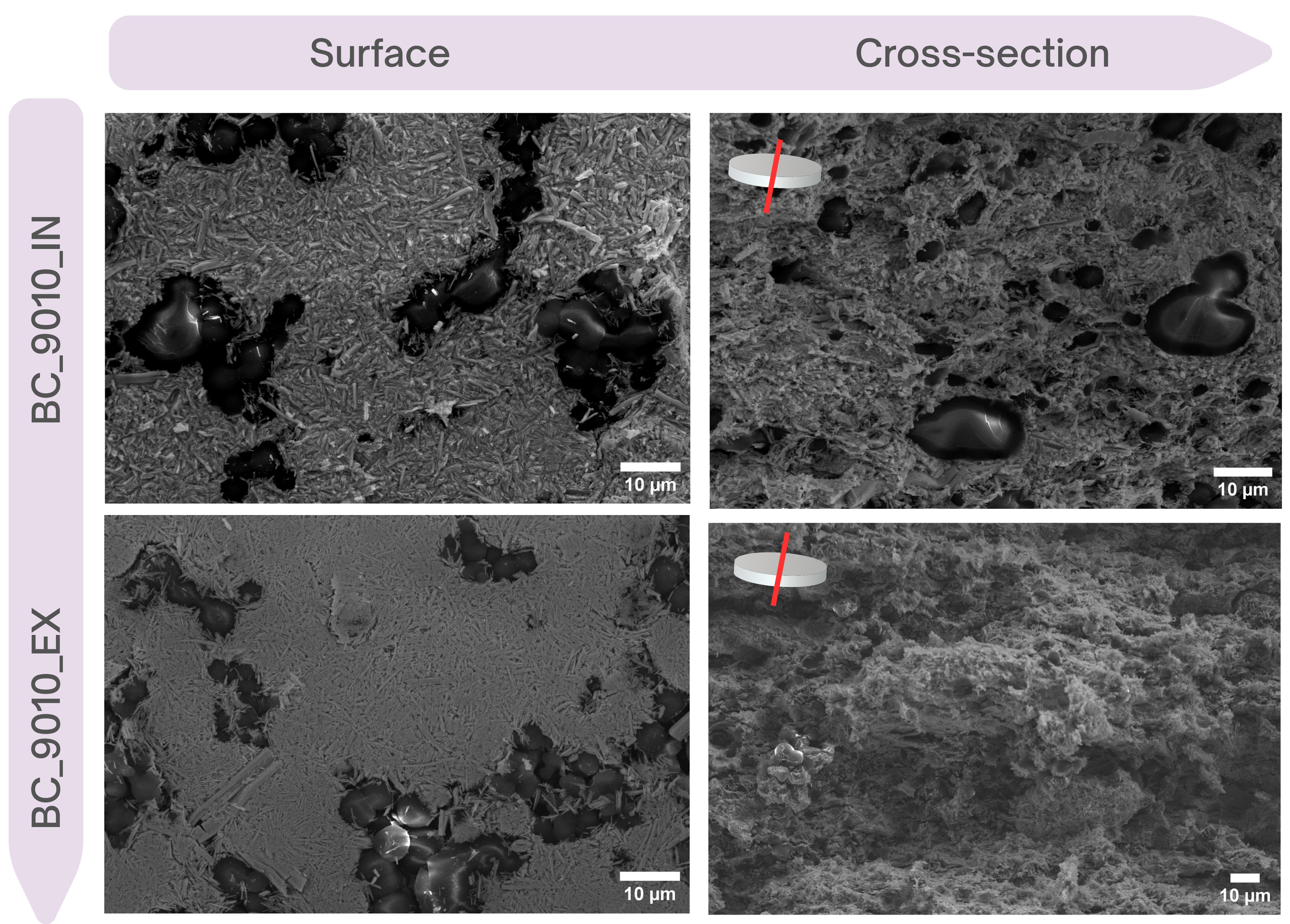
XRD analysis revealed a single-phase BiSI structure in the initial powder. It was preserved in the pressed pellets even after application of in-situ and ex-situ thermal treatments.

Scanning electron microscopy (SEM)

The initial powder consists of nanorods with an average wheight of 300 nm, and c- C particles with an average diameter of 5.7 µm.



in-situ thermal treatment drives a microstructural changes, including sintering of BiSI nanorods and coalescence of carbon particles. These effects were absent in pellets treated with the ex-situ method.



Prototype devices

Electrical characterization through current-voltage (I-V) measurements under dark conditions revealed a significant difference in performance.

The device based on the ex situ pellet exhibited a lower dark current and a higher resistivity of 4.20 × 10^9 Ω·cm two orders of magnitude greater than the in situ device 3.25 × 10^7 Ω·cm), which showed a correspondingly higher dark current.

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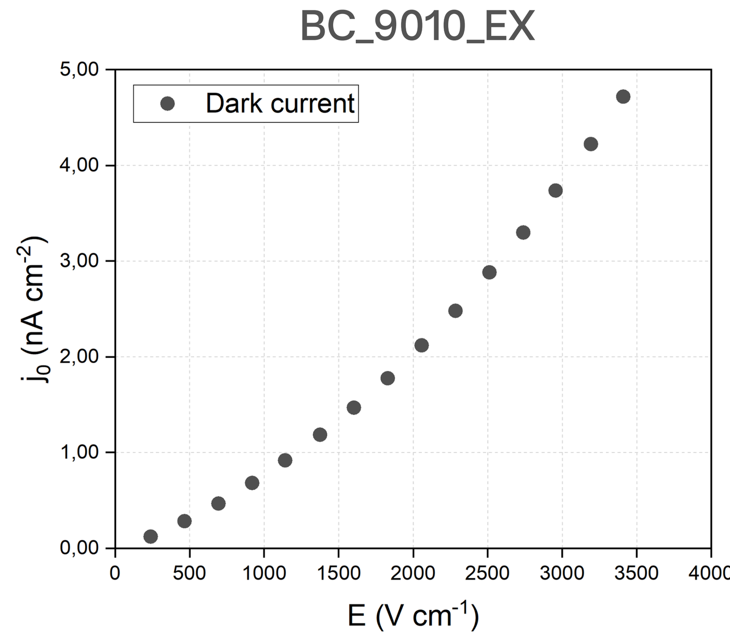

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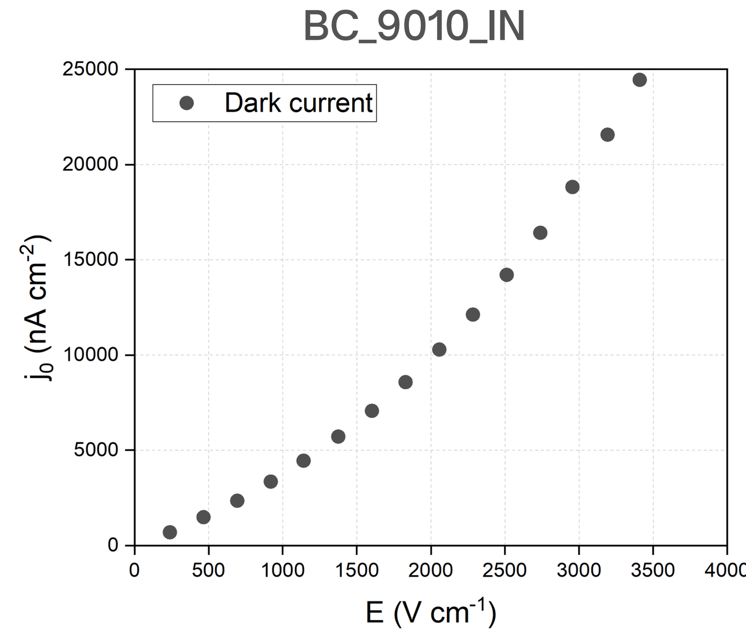

Conclusions

- No coalescence of carbon particles or sintering of BiSI nanorods were observed in ex situ treated pellets.
- The in situ treatment induces particle coalescence both on the surface and within the pellet's interior.
- The ex situ method proved more practical for fabrication, as the pellets were easier to demold compared to those subjected to in situ treatment.
- Preliminary electrical characterization indicates that the ex situ pellet exhibits the most favorable properties for the applications in radiation detectors devices.

Future work

- Evaluate different BiSI- a-C nanocomposite ratios to compare electrical properties and detector response.
- Explore alternatives to facilitate demolding of in situ thermally treated pellets.
- Characterize prototype device performance under X-ray exposure to evaluate their efficiency and sensitivity as radiation detectors.

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References

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