Microstructure and Transport Property Evaluation of Nanostructured Bi2Te3 Synthesized through different solution chemical routes

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Outline

Background

- Nanostructures Bi_2Te_3
- Chemical solution synthesis
- Microwave assisted synthesis

Experimental synthesis work

- Synthesis of thermoelectric Nanomaterials
- Consolidation of thermoelectric Nanomaterials

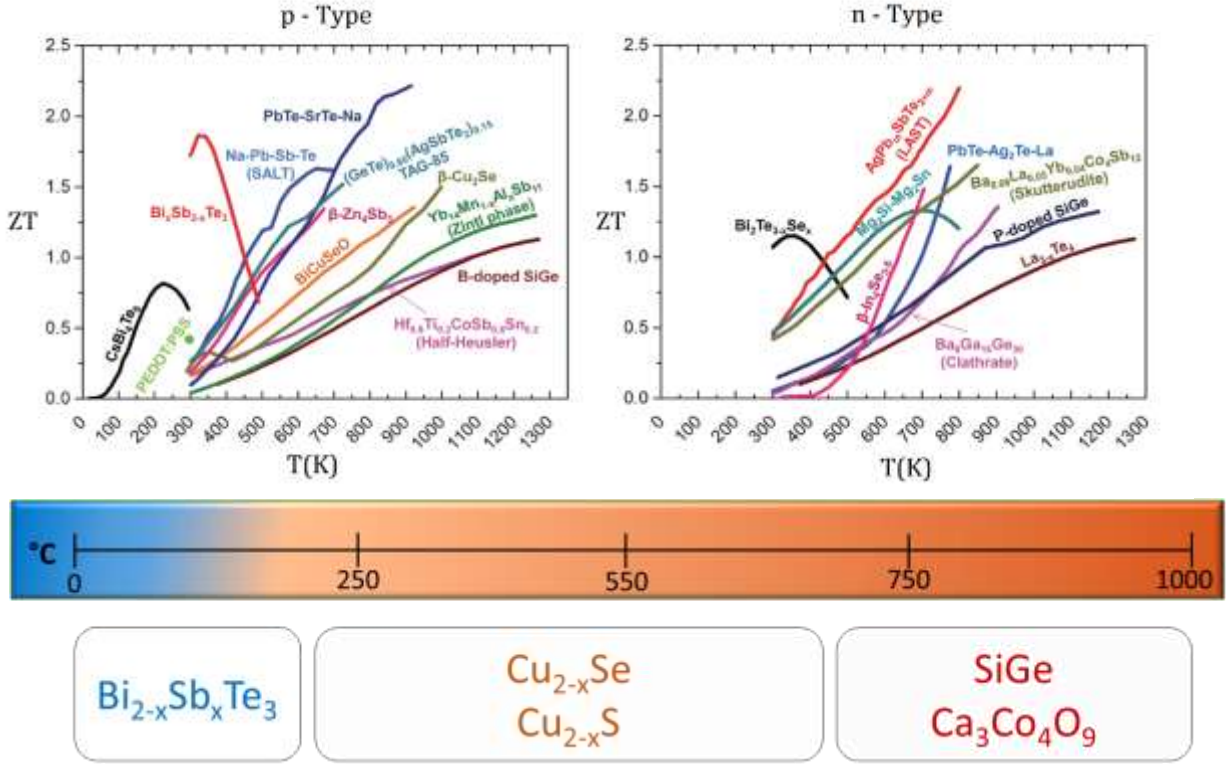
Characterization

- Structural and Morphological Characterization
- Transport property evaluation

Conclusion

Background

Bi_2Te_3 is the best known thermoelectric material in room temperature



*Rull-Bravo, M.; Moure, A.; Fernández, J.F.; Martín-González, M. Skutterudites as thermoelectric materials: Revisited. *RSC Adv.* **2015**, *5*, 41653–41667, doi:10.1039/c5ra03942h.

Background

Synthesis methods of Bi_2Te_3

- Low cost
- Reproducible
- Green
- Control the size
- Control surface chemistry

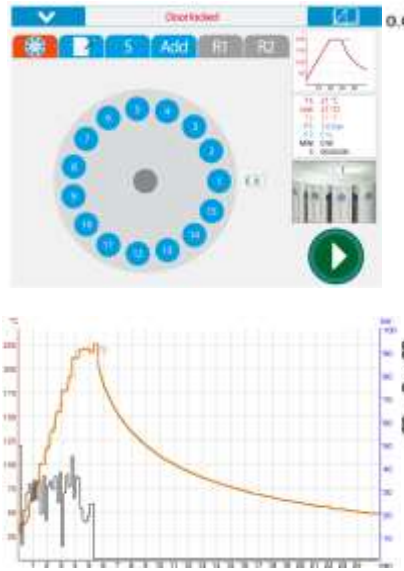
Advantages and disadvantages of Bi_2Te_3 nanostructure production techniques.

Production Technique	Efficient	Cost-effective	Device-quality	Developed Size	Comments
Solvothermal or hydrothermal	ZT = 1.16	Low cost	Best	~ 10 nm	Cost effective synthesis
Straight forward arc-melting	Low	Costly	Fair	Pellets	Difficult to microstructural characterization
Bridgman	Low	High cost	Fair	Single crystalline	Difficult to device applications
Mechanical alloying	Medium	Costly	Good	~ 10 nm	Required high temperature and pressure
Polyol	Medium	Medium Cost	Poor	~ 200 nm	Use the toxic chemical
Water-based chemical reduction	Low	Medium Cost	Poor	~ 300 nm	Do not control the particle size
Chemical oxidation	Low	Medium Cost	Poor	Not uniform	Electrical properties cannot be improved
Wet chemical	Medium	Low cost	Good	~ 30 nm	Use the toxic chemical
Refluxing	Medium	Costly	Good	~ 15 nm	Handled so much carefully
Cryogenic grinding	Medium	Costly	Poor	~ 70 nm	May not be suitable for device manufacturing
Large-scale zone melting	ZT = 1.15	Costly	Good	Nanostructure	Difficult to microstructural characterization
Facile solution	Medium	Costly	Fair	~ 22 nm	Use the toxic chemical

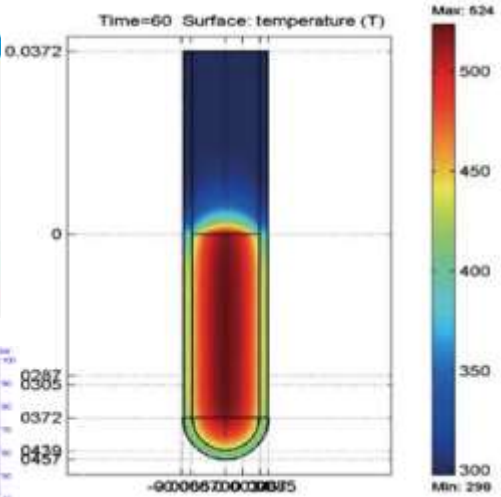
*Mamur, H.; Bhuiyan, M.R.A.; Korkmaz, F.; Nil, M. A review on bismuth telluride (Bi2Te3) nanostructure for thermoelectric applications. *Renew. Sustain. Energy Rev.* 2018, *82*, 4159–4169, doi:10.1016/j.rser.2017.10.112

Microwave Assisted Heating of Bi2Te3

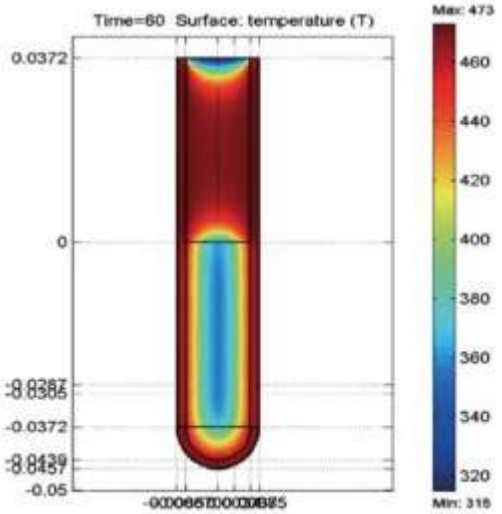
- Fast
- Reproducible
- Energy efficient
- Control the reaction
- High yield



Microwave heating



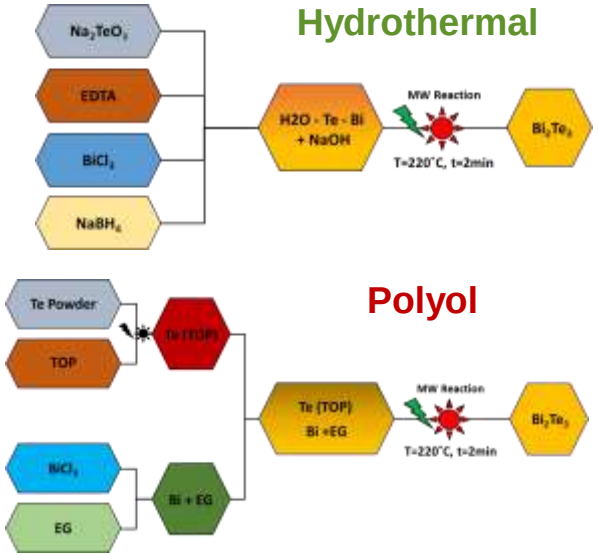
Conventional heating

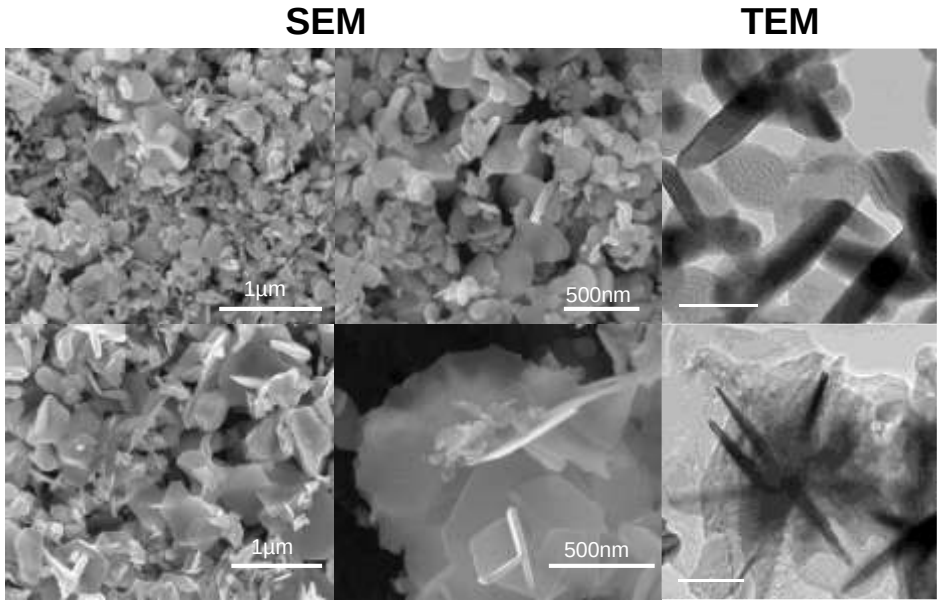


*Schanche, J. S. Mol. Diver. **2003**, 7, 291– 298

Experimental work

Synthesis and characterization of Nanostructured Bi_2Te_3





Experimental work

Consolidation of thermoelectric Nano-powders

Spark plasma sintering SPS

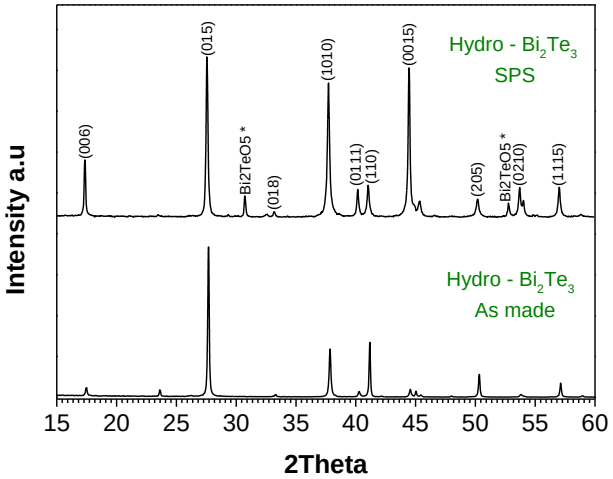
Temperature was set to 400 °C with a heating rate of 30°C /min and 1min dwell time. 50 MPa Pressure was applied gradually during the SPS process.

15 mm inner diameter graphite cylinders

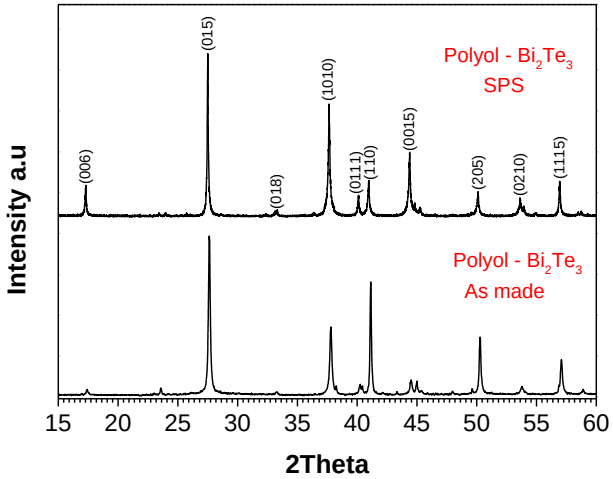
Experimental work

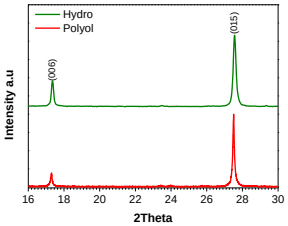
XRD,SEM– Nanostructured Bi_2Te_3

Hydrothermal



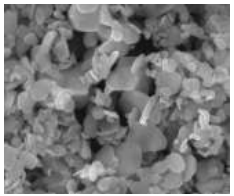
Polyol

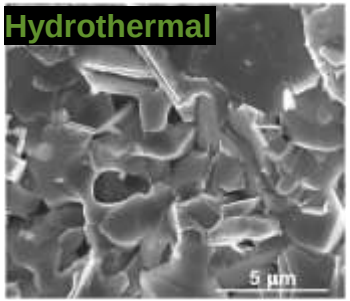


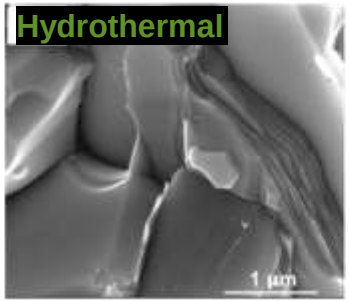


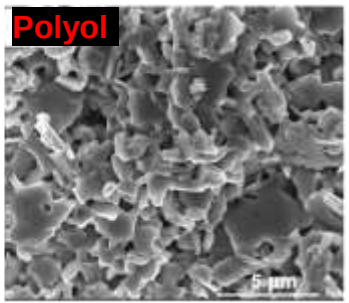
Hydro: $I_{006} / I_{015} = 0.38$

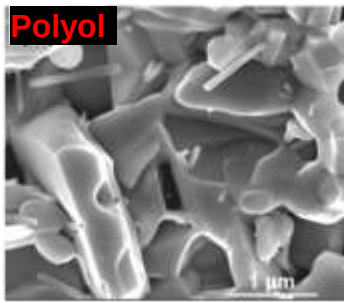
Polyol: $I_{006} / I_{015} = 0.19$

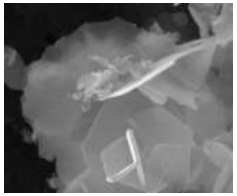








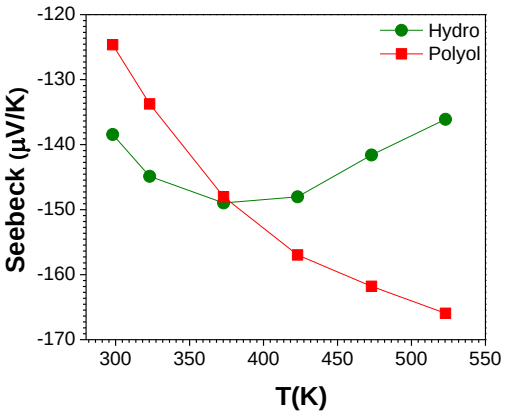


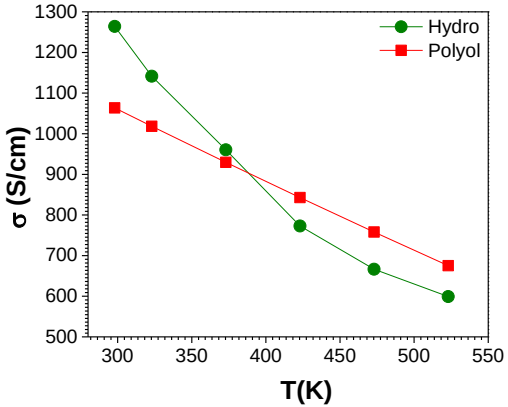


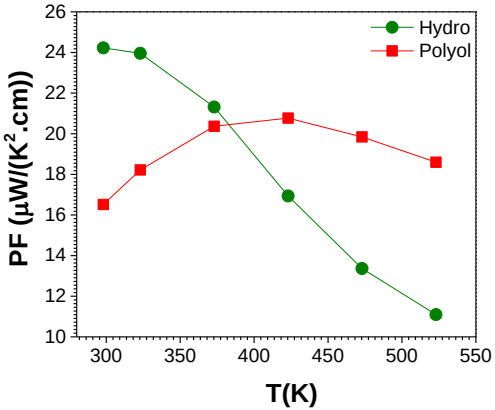
Characterization

Transport property evaluation

$$ZT = \frac{S^2\sigma}{\kappa}T$$







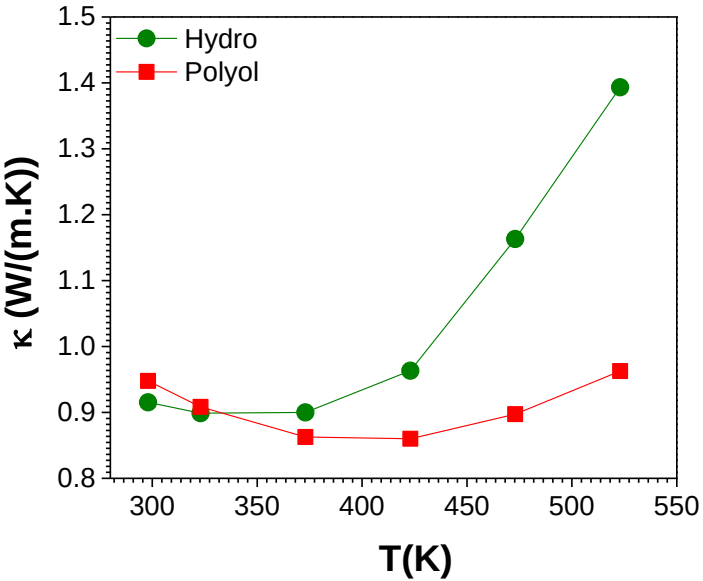
Characterization

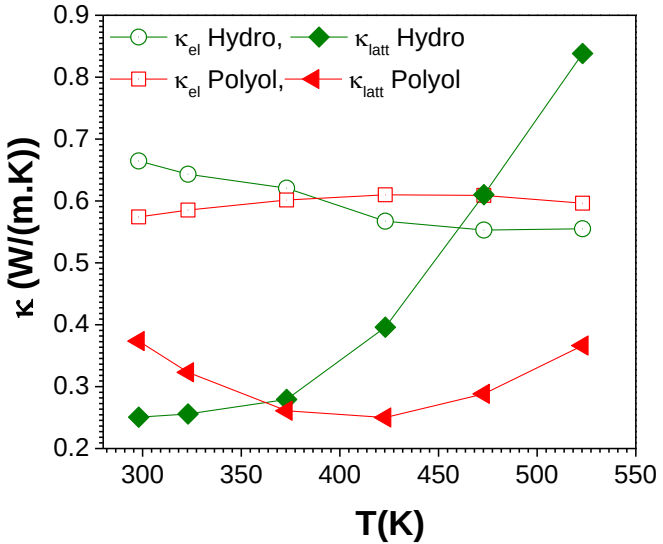
Transport property evaluation

$$ZT = \frac{S^2\sigma}{\kappa}T$$

$$\kappa_{tot} = \kappa_e + \kappa_{latt}$$

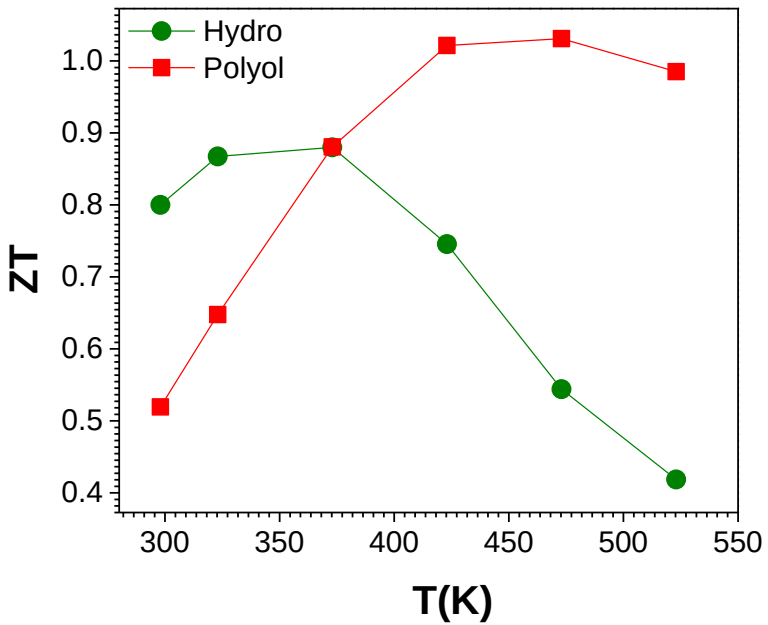
$$\kappa_{tot} = \kappa_e + \kappa_{latt} + \kappa_{amb}$$





Characterization

Transport property evaluation



- **ZT = 1.04** (at 440 K),(Bi_2Te_3) n-type
- **ZT = 0.88** (at 373 K),(Bi_2Te_3) n-type

Conclusion

- Chemical solution synthesis Bi_2Te_3 presented, Polyol and Hydrothermal.
- Control the size, morphology , surface chemistry
- Microwave assisted synthesis : Short reaction time 2 min, high-yield 93%
- Good performance for of Bi_2Te_3
- Promising synthesis route for large scale fabrication of TE materials

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Thank you