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Processing, Microstructure, and Transport Properties in Nanostructured Bi_2Te_3

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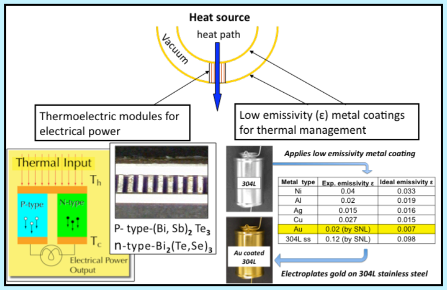
Nanostructured Bi_2Te_3 based thermoelectric materials have been shown to yield high ZT, through a lower thermal conductivity.

Question: How does processing affect microstructure and thermoelectric performance in these novel nanostructured alloys?

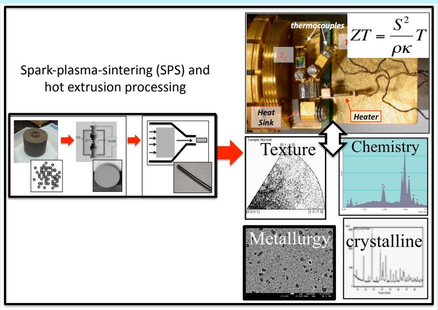
Answer: Processing impacts ZT by controlling grain size, porosity and texture. However, these do not all change ZT in concert.

Scientific approach

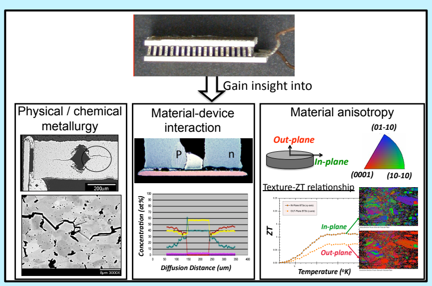
TE device: concept and design



Processing and Property

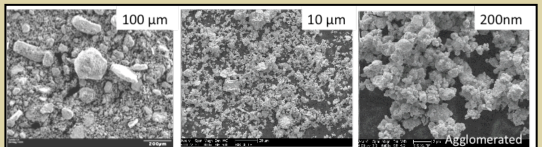


Materials Science for TE modules



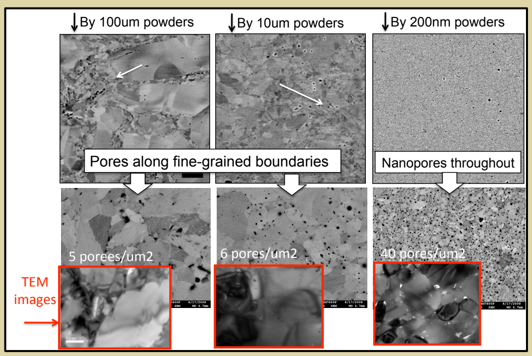
Physical properties and microstructure

Test Matrix: feedstock powder sizes and processing parameters



Pure B_2Te_3 Sample ID	Nominal powder size (µm)	SPS condition		Extrusion condition	
		Temp (°C)	Pressure (MPa)	Temp (°C)	Pressure (MPa)
BT3	100	400	50	N/A	N/A
BT10	10	400	50	N/A	N/A
NBT20	0.2	400	50	N/A	N/A
BT40	0.2	400	300	N/A	N/A
BT extrusion	10	400	80	420	80

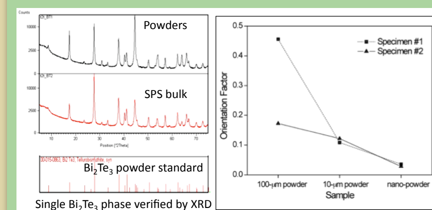
Starting powder size dictates final grain size and porosity



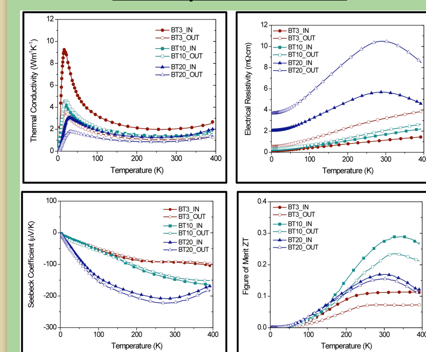
- A significant difference in grain size, pore size, distribution and density was observed among the SPS Bi_2Te_3 using 100um, 10um and 200nm powders.
- Pore density in the nanostructured NBT20 is ~10 times higher than in the coarse-grained BT3 and BT10.

Texture and TE properties

Texture decreases with decreasing grain size

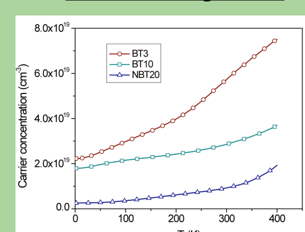


Nanoscale grains increase electrical resistivity and decrease ZT



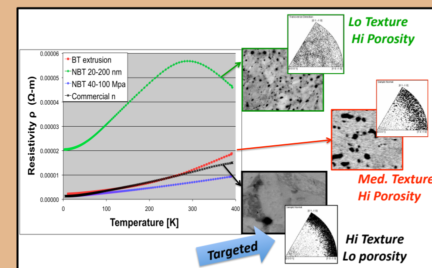
High Seebeck coefficient and low thermal conductivity of the nanostructured Bi_2Te_3 did not yield high ZT as expected due to high resistivity.

Source of low ZT: Carrier concentration decreases with grain size



On-going activities

SPS + additional hot extrusion improve ZT



Electrical resistivity reduces with increased SPS pressure and/or additional extrusion.

Conclusions

Nanostructuring Bi_2Te_3 under SPS conditions leads to:

- Higher nanopore density and reduced crystallographic texture.
- Decreased thermal conductivity, but nanopores appear to trap carriers that increase resistivity and decrease ZT.
- Change in texture that may also reduce ZT.

Publications

1. " Structure of the (0001) basal twin boundary in Bi2Te3" D. L. Medlin, N. Yang, J. Snyder etc. JApplPhys, 108, 2010.
2."Thermoelectric and transport properties of nanostructured Bi2Te3 by spark plasma sintering" Zhihui Zhang; P. A. Sharma; N. Yang, ; E. J. Lavernia, Journal of Materials Research, 26(3), 2011, in press.

Sandia National Laboratories

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