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EPSRC Thermoelectric Network Meeting

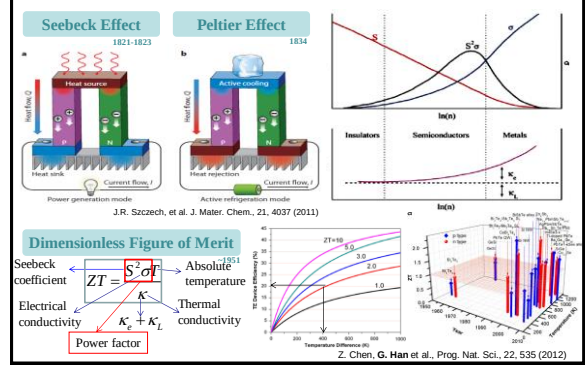
Design and Synthesis of New Layered Metal (III A, IV A, V A) Selenide Nanostructures for Thermoelectric Applications

Dr Guang Han

Prof. Duncan Gregory's Inorganic Solid State and Materials Chemistry group, WestCHEM, School of Chemistry, University of Glasgow, UK

21st April 2016

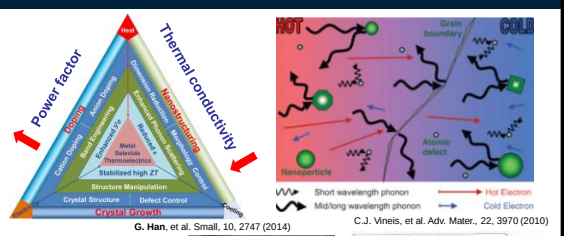
Background: Thermoelectrics (TE)



J.R. Szczech, et al. J. Mater. Chem., 21, 4037 (2011)

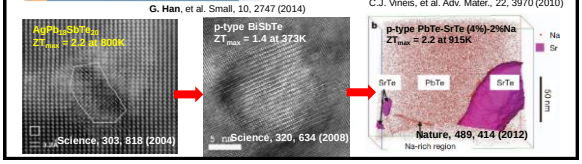
Z. Chen, **G. Han** et al., Prog. Nat. Sci., 22, 535 (2012)

Background: Thermoelectrics (TE)



G. Han, et al. Small, 10, 2747 (2014)

C.J. Vineis, et al. Adv. Mater., 22, 3970 (2010)

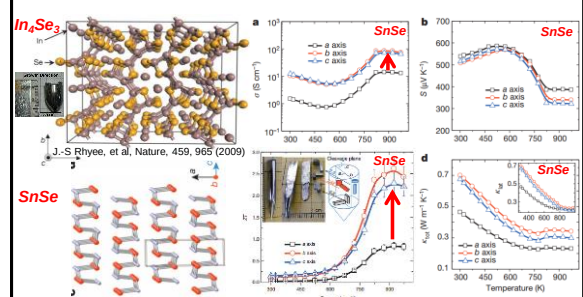


Science, 303, 818 (2004)

Science, 320, 634 (2008)

Nature, 489, 414 (2012)

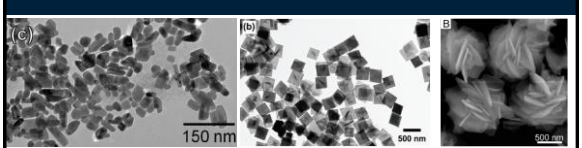
New Layered Metal Selenide TE Materials



J.-S Rhyee, et al, Nature, 459, 965 (2009)

L.-D. Zhao, …, M.G. Kanatzidis, Nature, 508, 373 (2014)

Solution Synthesis of SnSe Nanostructures



SnCl2+di-tert-butyl diselenide in dodecylamine + dodecanethiol
M.A. Franzman, et al, JACS, 132, 4060 (2010)

SnCl2+ trioctylphosphine selenide TOP-Se in oleylamine + hexamethyldisilazane
D.D. Vaughn II, et al., ACS Nano, 5, 8852 (2011)

SnCl4•5H2O + SeO2 in oleylamine
L. Li, et al., JACS, 135, 1213 (2013)

Disadvantages of the synthesis

- *Small-scale synthesis*
- *Expensive solvent*
- *Expensive and/or toxic precursors*
- *Surfactant/organic ligand coating: potential detrimental influence on electrical performance*

Synthesis strategy in SnSe Nanoplates

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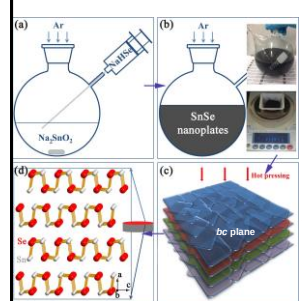

Materials Design and Synthesis

- *Surfactant free*
- *Effective morphology control*
- *Large-scale solution synthesis*
- *Fast Synthesis*
- *Cheap and environmentally friendly precursors*

Thermoelectric Performance

- *Enhanced power factor*

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G. Han, et al., D.H. Gregory*, Angew. Chem. Int. Ed., DOI: 10.1002/anie.201601420 (*VIP Paper*)

Surfactant-Free p-type SnSe Nanoplates

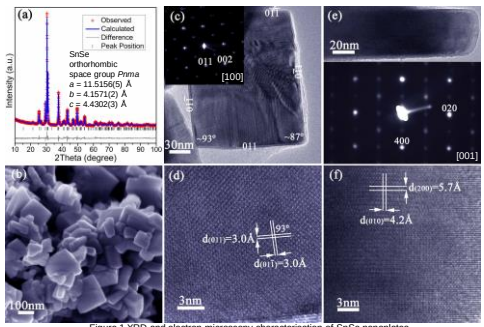

Figure 1 XRD and electron microscopy characterisation of SnSe nanoplates with {011} side facets and {100} surfaces

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Surfactant-Free p-type SnSe Nanoplates

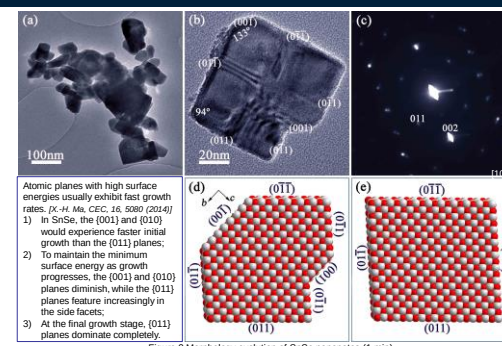

Figure 2 Morphology evolution of SnSe nanopates (1 min)

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Surfactant-Free p-type SnSe Nanoplates

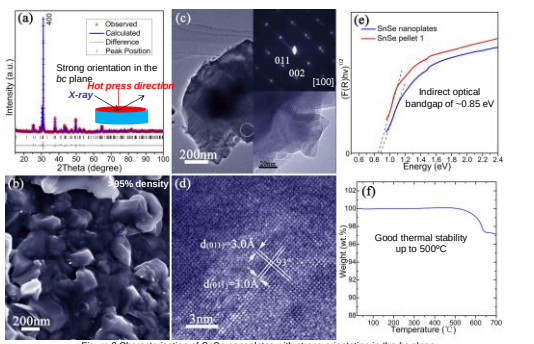

Figure 3 Characterisation of SnSe nanoplates with strong orientation in the *bc* plane

G. Han, et al., D.H. Gregory*, Angew. Chem. Int. Ed., DOI: 10.1002/anie.201601420 (*VIP Paper*)

Surfactant-Coated SnSe Nanoparticles

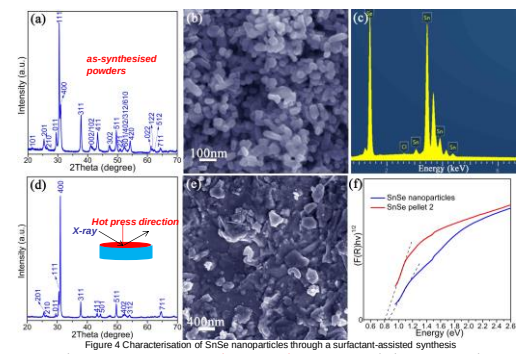

Figure 4 Characterisation of SnSe nanoparticles through a surfactant-assisted synthesis

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Surfactant-Free p-type SnSe Nanoplates

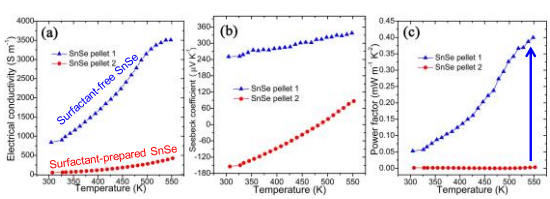

Figure 5 Thermoelectric performance evaluation of SnSe pellets (error: S 5%, σ 5%, $S^2\sigma$ 10%)

G. Han, et al., D.H. Gregory*, Angew. Chem. Int. Ed., DOI: 10.1002/anie.201601420 (*VIP Paper*)

Conclusions

- A simple, quick surfactant-free and energy-efficient solution synthesis yields SnSe nanoplates in gram quantities. The nanostructured pellets exhibit exceptional power factors, surpassing those of polycrystalline and surfactant-coated counterparts.
- The technique should be readily adaptable to include dopants and amendable to the discovery of further materials, both p- and n-type, with enhanced thermoelectric properties.

VIP Thermoelectrics Very Important Paper Angewandte International Edition

International Edition: DOI: 10.1002/anie.201601420
German Edition: DOI: 10.1002/ange.201601420

Facile Surfactant-Free Synthesis of p-type SnSe Nanoplates with Exceptional Thermoelectric Power Factors

*G. Han, S.R. Popuri, H.F. Greer, J.-W.G. Bos, W.Z. Zhou, et al., D.H. Gregory**

Acknowledgement

Group Leader

- Prof. Duncan Gregory (*UofG, UK*)

Collaborators

- Dr Jan-Willem Bos,
  Dr Srinivas Popuri (*Heriot-Watt*)
- Prof Wu-Zong Zhou,
  Dr Heather Greer (*St Andrews*)

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Thank you for your attention!

Contact details

For discussion and/or collaboration research, please contact:

Dr Guang Han Guang.Han@glasgow.ac.uk

Prof Duncan H. Gregory Duncan.Gregory@glasgow.ac.uk

Address: WestCHEM, School of Chemistry, University of Glasgow, UK

Other publications involved in this talk

For other metal selenide nanostructures involved in this talk, please refer to the following publications.

- New Crystal Structure: In_3Se_4
  http://pubs.rsc.org/en/Content/ArticleLanding/2014/CE/C3CE41815D#!divAbstract
  http://pubs.acs.org/doi/abs/10.1021/cg401269p
  http://scitation.aip.org/content/aip/journal/apl/103/26/10.1063/1.4857655
  http://pubs.rsc.org/en/Content/ArticleLanding/2014/TC/c4tc01025f#!divAbstract
- Doped Structures: S-doped In_3Se_4 & In-doped Bi_2Se_3
  http://pubs.rsc.org/en/content/articlelanding/2014/ta/c4ta00045e#!divAbstract
  http://pubs.rsc.org/en/Content/ArticleLanding/2015/TA/c5ta00688k#!divAbstract0
- Rational morphology design: Bi_2Te_3 whiskers
  http://pubs.acs.org/doi/abs/10.1021/am5078528
- Thermoelectric Review
  http://onlinelibrary.wiley.com/doi/10.1002/smll.201400104/full