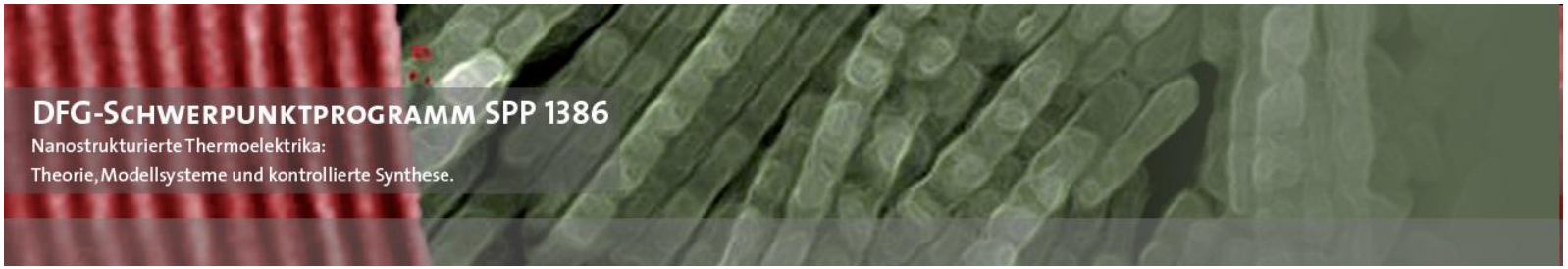
Leibniz Institute for Solid State and Materials Research Dresden



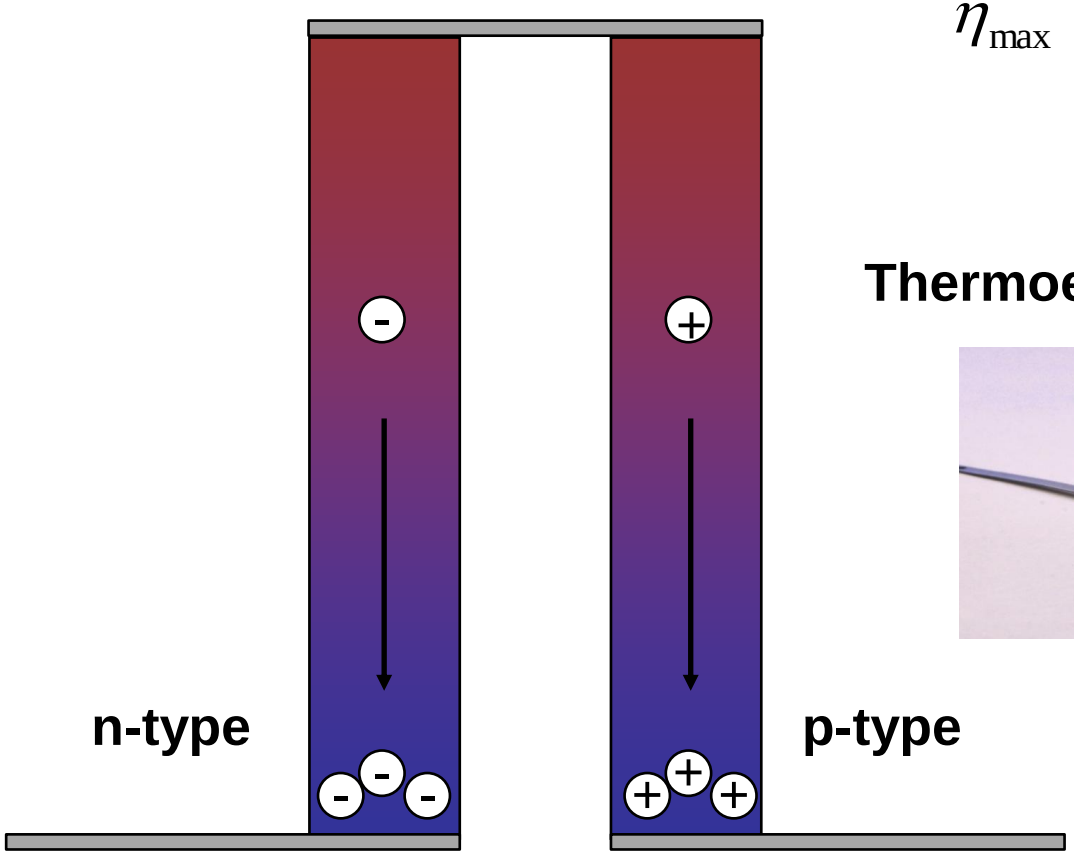
Nanocrystalline silicon with tungsten silicide inclusion phases: Morphology and thermoelectric properties

Gabi Schierning
Institute for Metallic Materials (IMW), IFW Dresden

Leibniz Association

Content

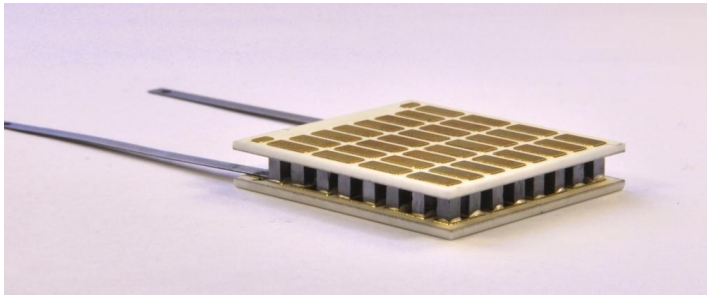
Thermoelectric generator



Best possible efficiency:

$$\eta_{\max} = \eta_{Carnot} \cdot \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_2}{T_1}}$$

Thermoelectric figure of merit: ZT

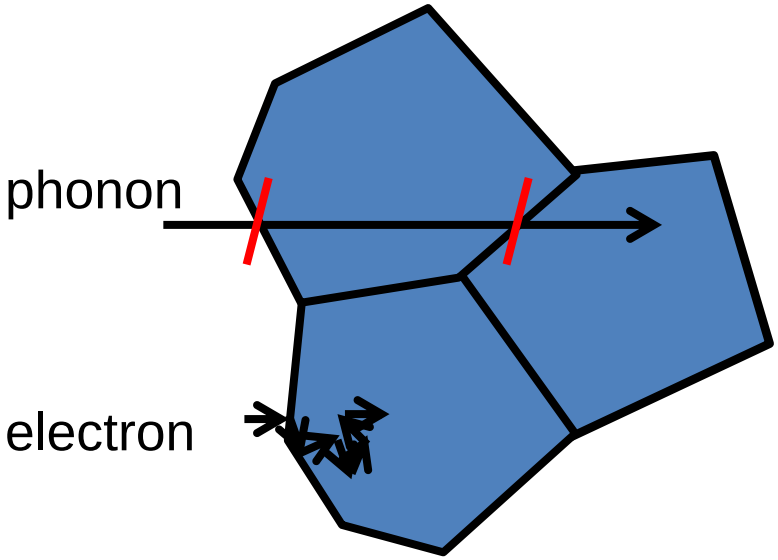


Material´s figure of merit *zT* and nanotechnology

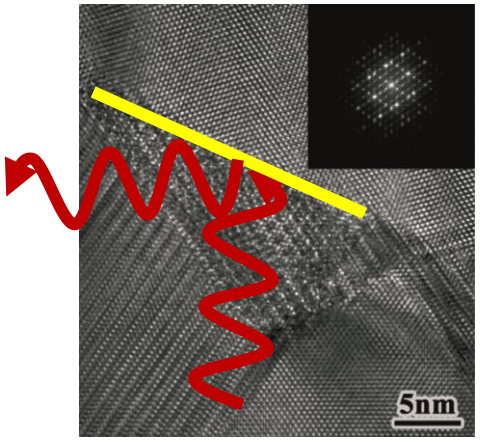
$$zT = \frac{\alpha^2 \cdot \sigma}{\kappa} T$$

α: Seebeck coefficient
σ: electrical conductivity
κ: thermal conductivity

Idea of nanostructuring approach

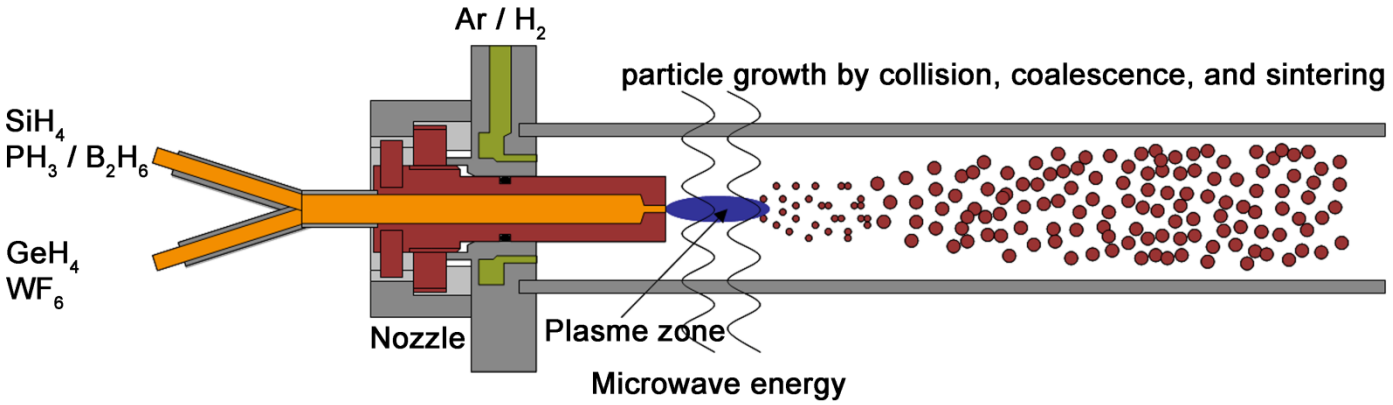


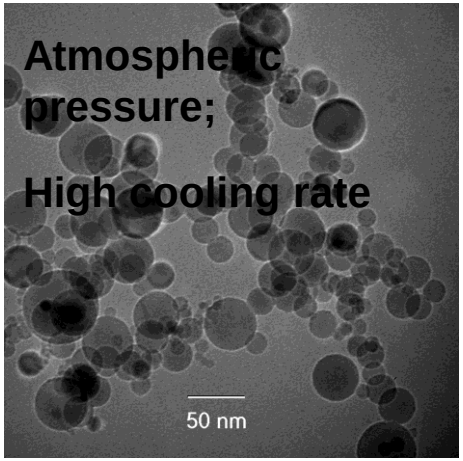
Introducing scattering centers to reduce thermal conductivity κ

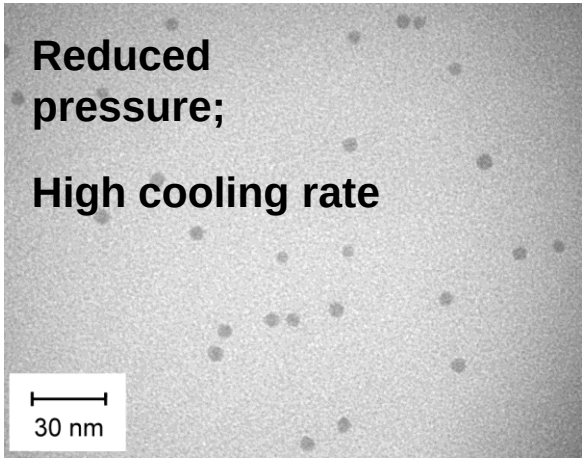


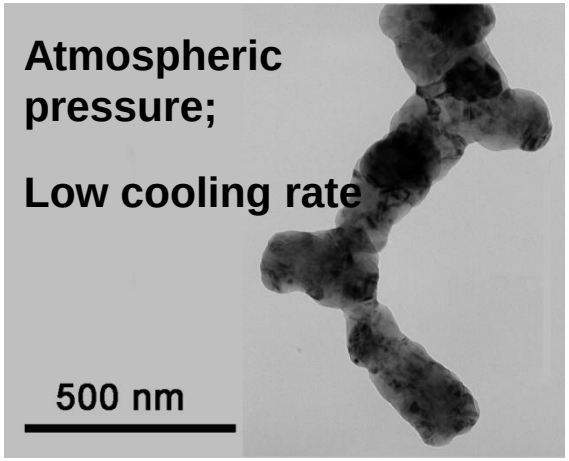
Content

Nanopowder synthesis from the gas phase





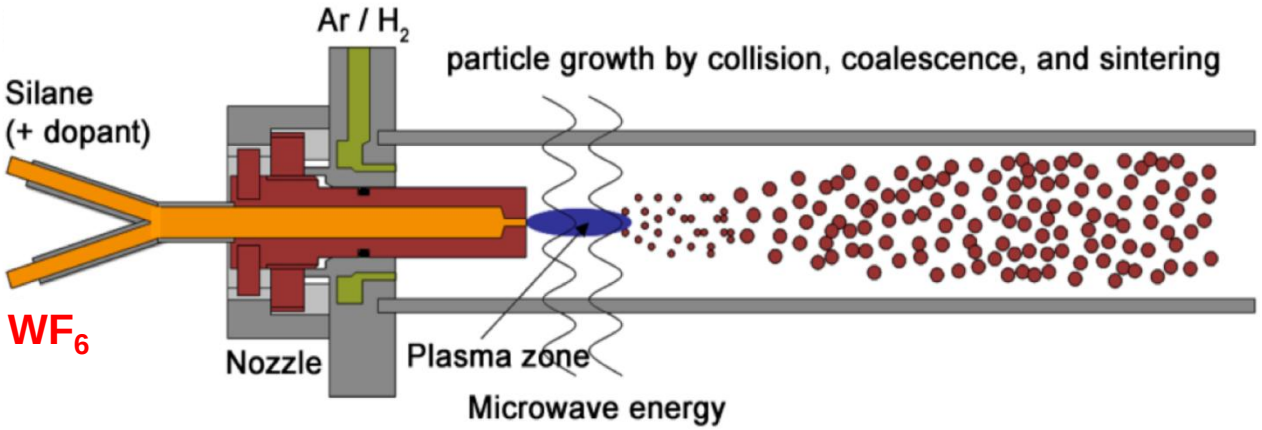


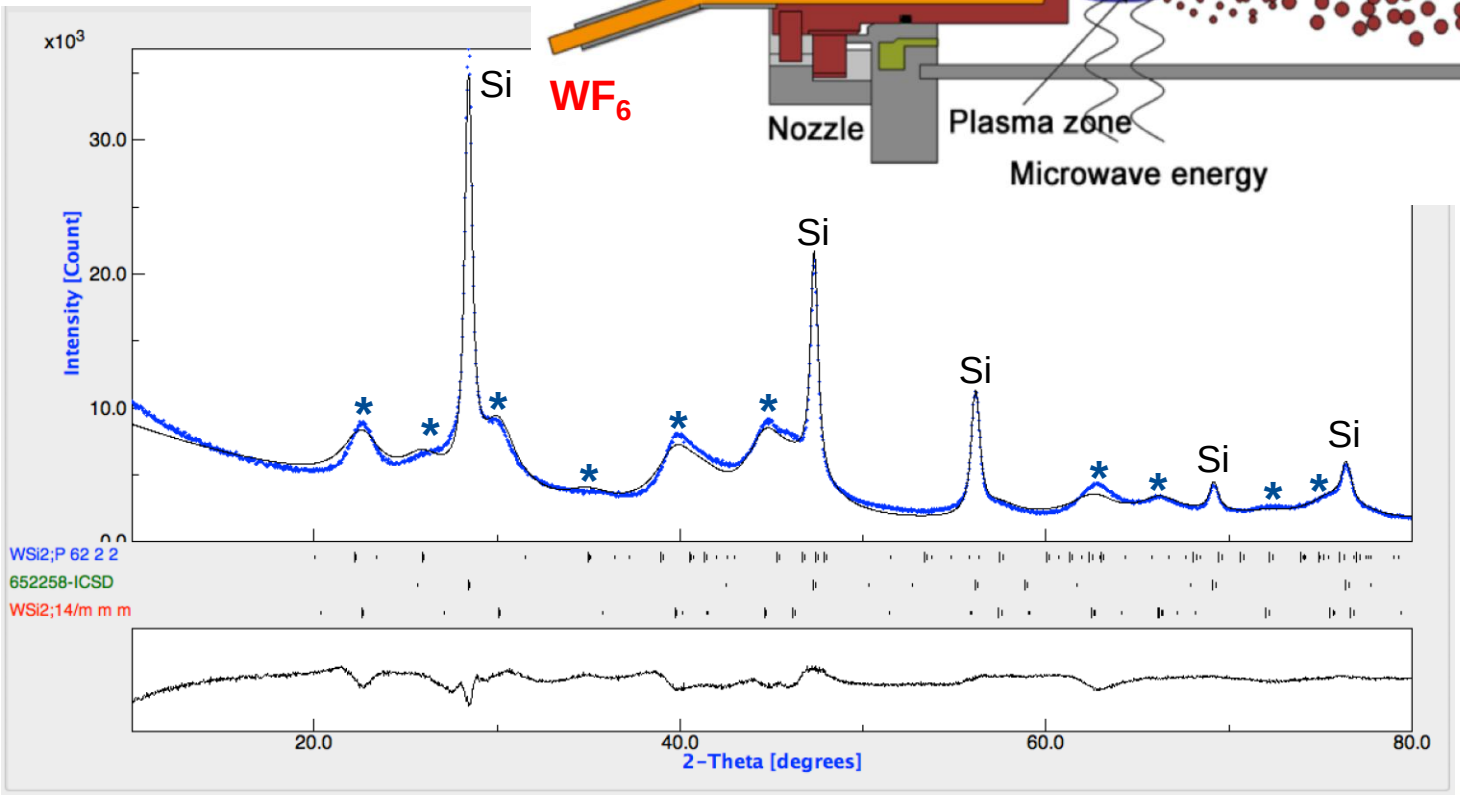


Nanopowder Synthesis: H. Wiggers, IVG, Univ. of Duisburg-Essen;

N. Petermann et al., J. Phys. D: Appl. Phys. 48, 314010 (2015).
N. Petermann et al., J. Phys. D: Appl. Phys. 44, 174034 (2011).

Perfectly intermixed two-component nanopowder: Si + WSi_2





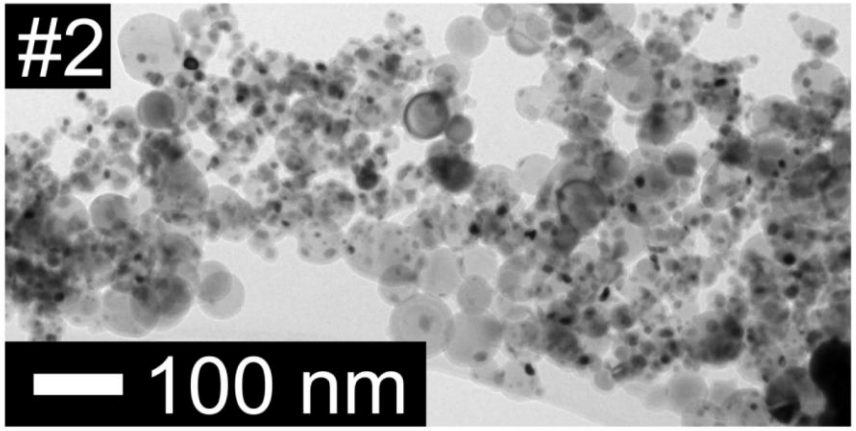
*** = WSi_2**

Ø ~ 4 nm

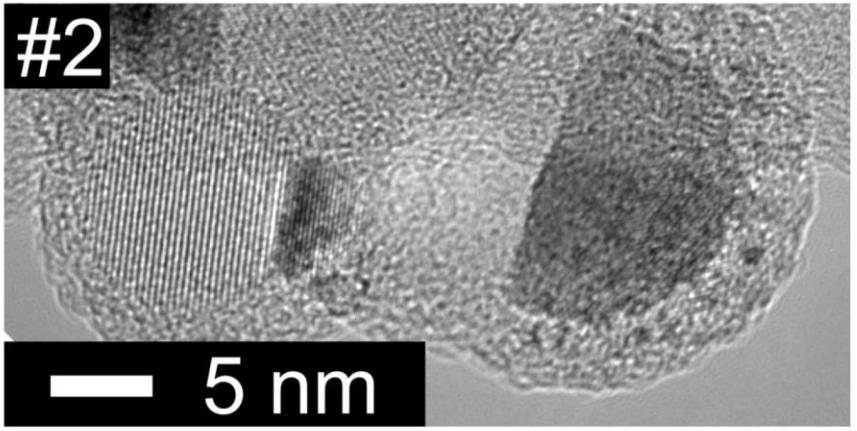
N. Petermann et al., J. Phys. D: Appl. Phys. 48, 314010 (2015).

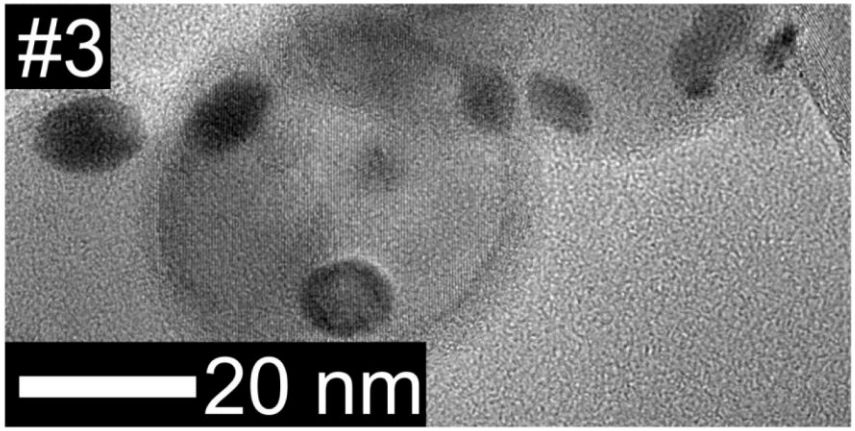
TEM of Si+WSi_2 samples with different W-content

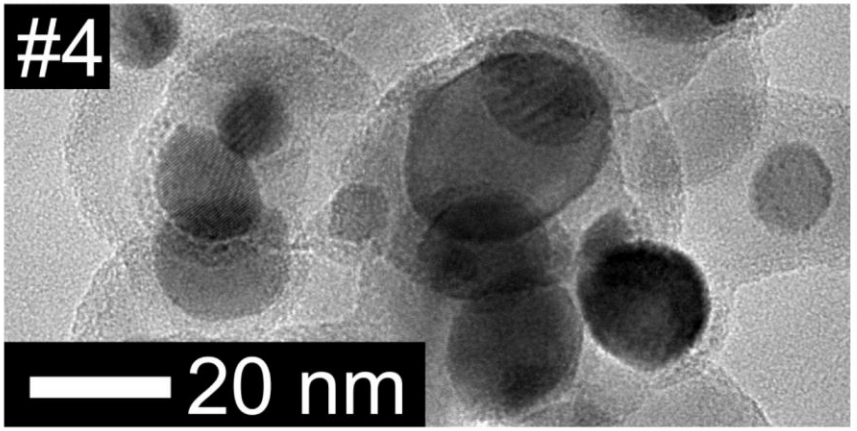
1 at.% W



1 at.% W





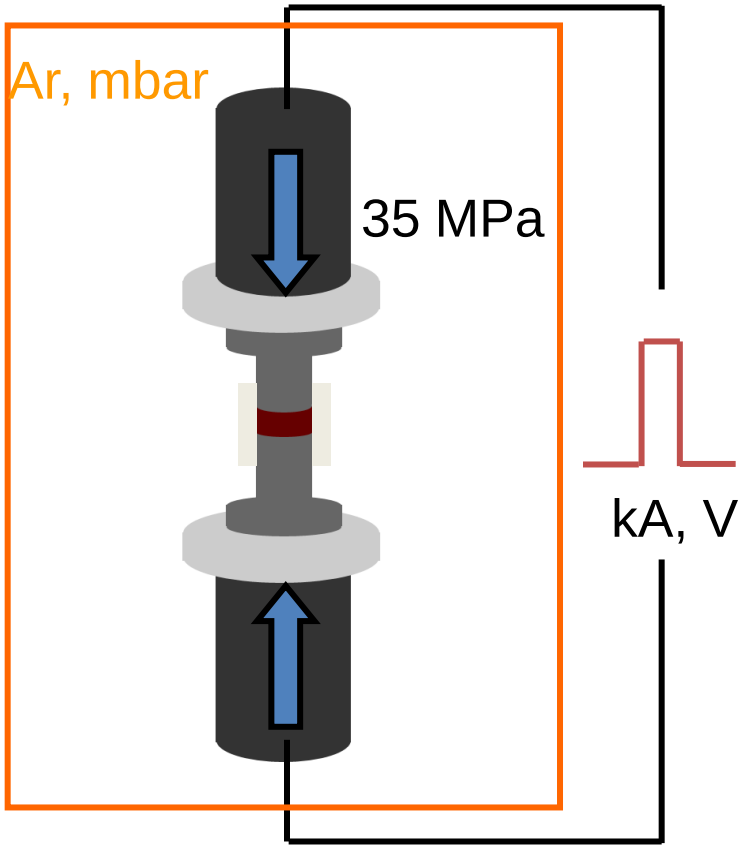


6 at.% W

17 at.% W

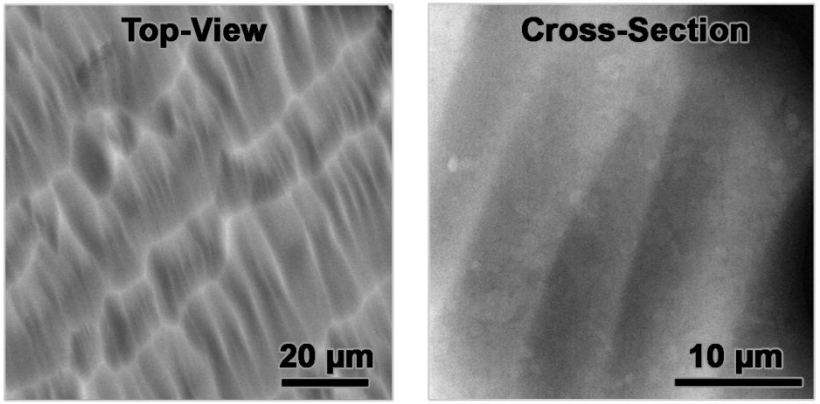
Samples and TEM by Tom Schneider and Hartmut Wiggers, Univ. Duisburg-Essen

Spark plasma sintering of thermoelectric powder



Influence of electric current on developing microstructure

- Formation of percolation network
- Redistribution of heat due to Peltier effect



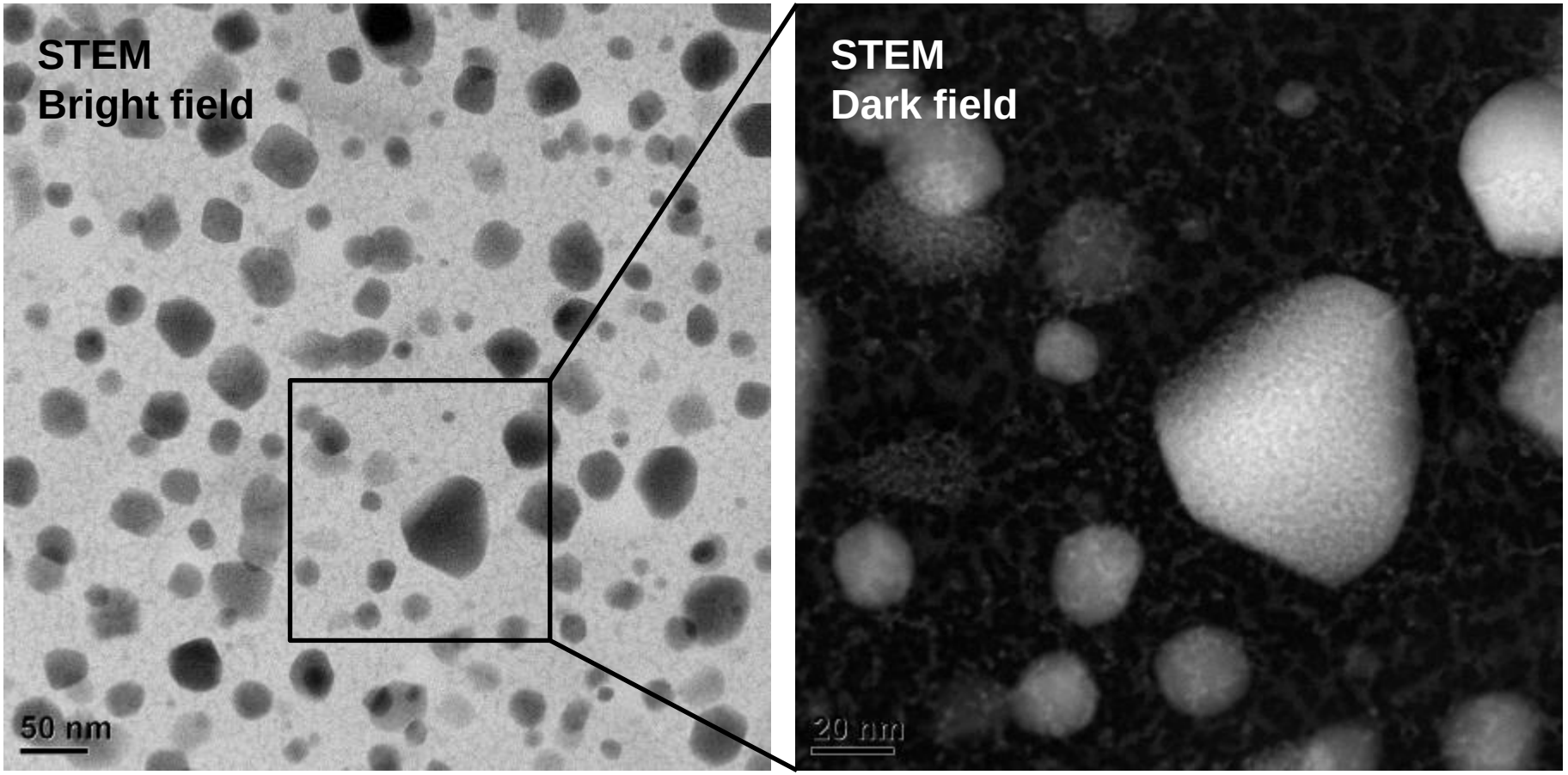
Review: O. Guillon et al., Adv. Eng. Mater. 16(7), 830-849 (2014).

A. Becker et al., Appl. Phys. Lett. 101, 013113 (2012).

D. Schwesig et al., Nanotechnology 22, 135601 (2011).

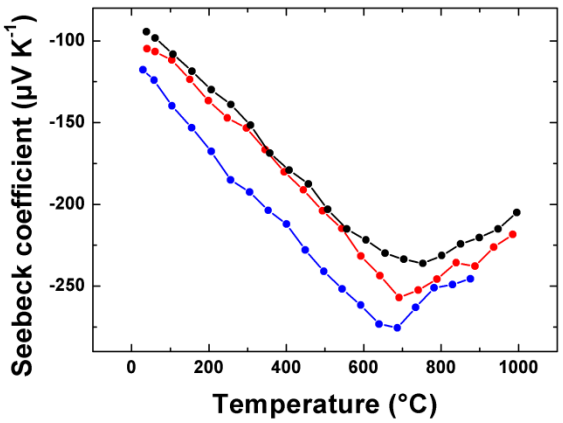
SPS machine and processing: M. Winterer, NPPT, Univ. of Duisburg-Essen

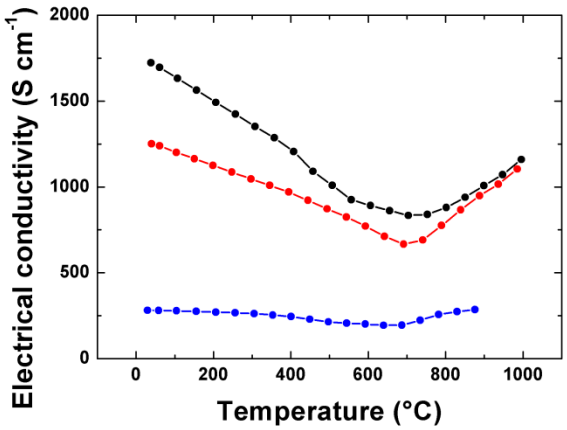
Microstructure of nanocrystalline Si + WSi_2 composite

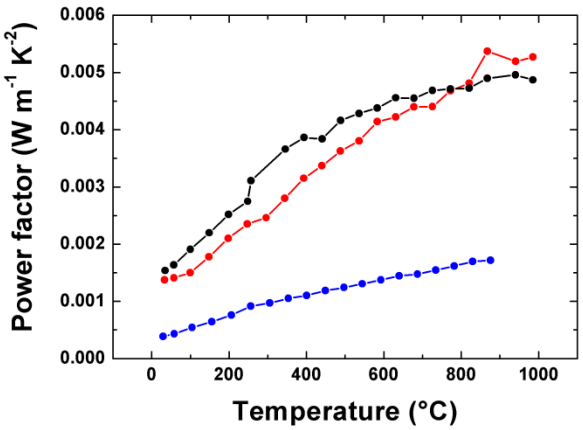


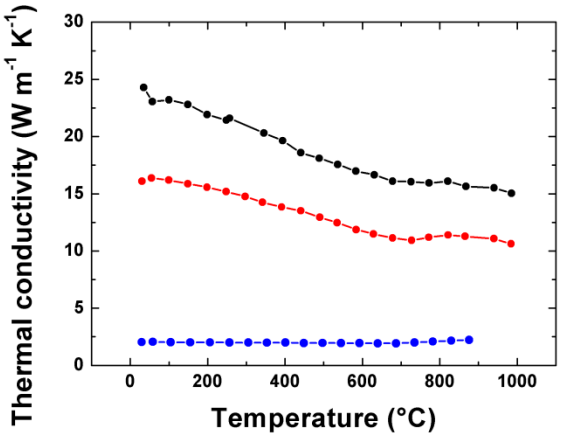
TEM by Mathis Müller and Hans-Joachim Kleebe, TU Darmstadt

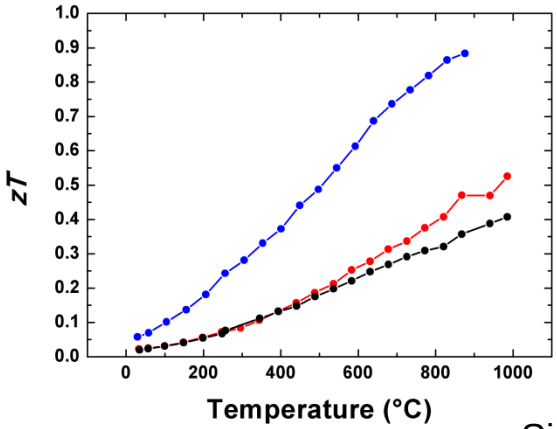
Thermoelectric performance of nano Si, SiGe, SI+WSi_2











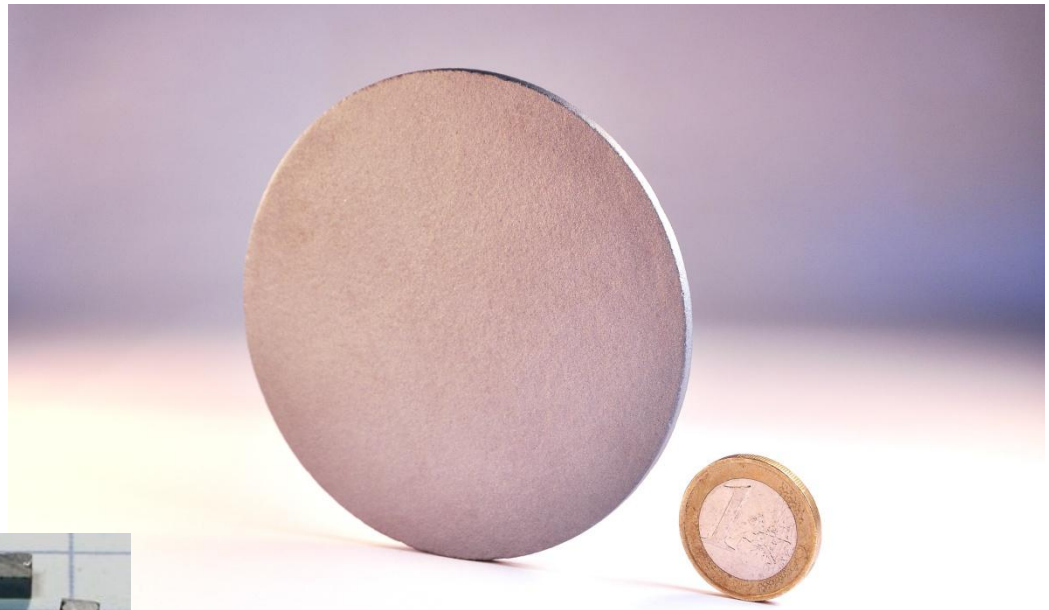
$Si_{80}Ge_{20}$ alloy

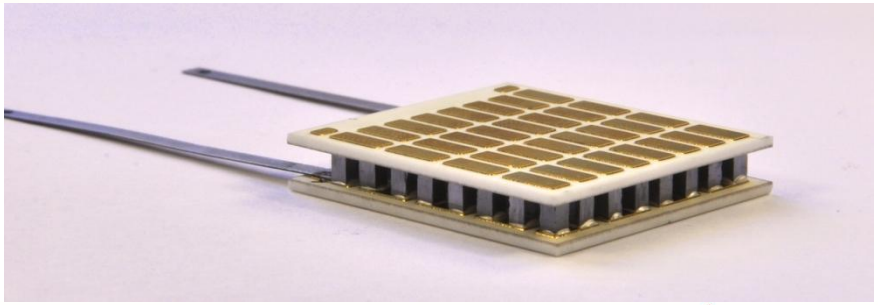
S+0.5 at.% WSi_2 composite

Si reference

SiGe: PSS A 213(3), 515-523 (2016).
Si + WSi_2: J. Phys. D 48, 314010 (2015).
Si reference: PCCP 16(47), 25701 (2014).

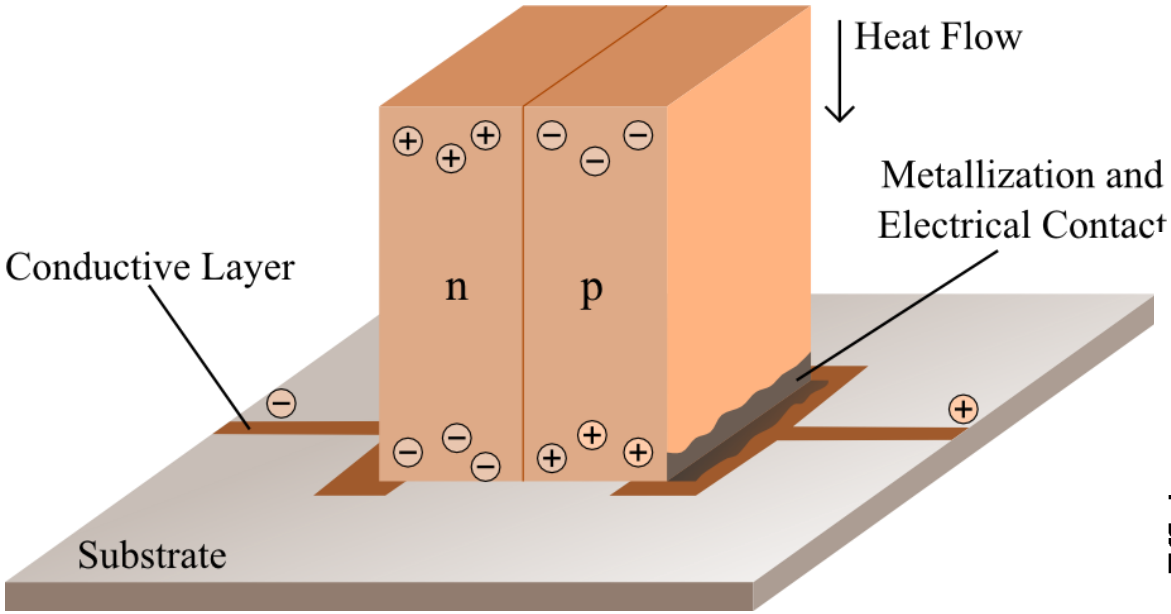
Devices: sustainable material and fully scalable processes

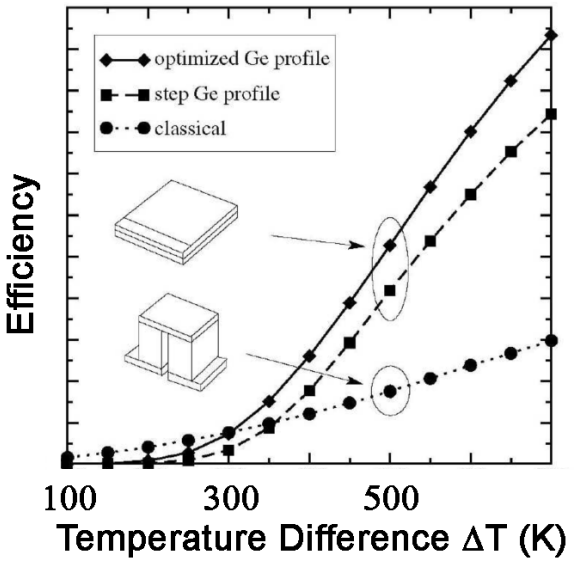




V. Kessler et al., J. Electr. Mater. 43 (5), 1389 (2014).
V. Kessler et al., Adv. Eng. Mater. 15 (5), 379 (2013).

Novel device concept





G. Span, M. Wagner, S. Holzer, T. Grasser, Thermoelectric power conversion using generation of electron-hole pairs in large area p-n junction, ICT 2006

Conclusion

- **Nanostructured bulk Si, SiGe and Si composites:**
  - **Tailoring the phonon mean free path**
  - **Improvement of figure of merit**
- **Thermoelectric performance:**
  - **Reasonable zT = 0.63 @ 950 °C (n-type, with WSi_2)**
  - **Harsh conditions possible by the implementation of novel device concepts**

Thank you for your attention!

Univ. Duisburg-Essen

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