Novel thermoelectric films based on a polymer-nanoparticle composite

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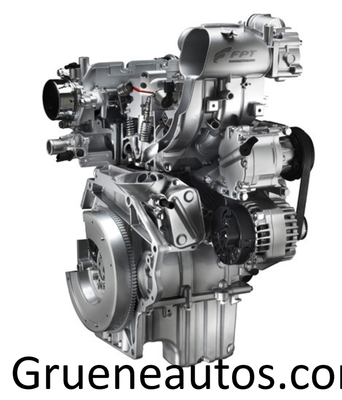
1. Motivation

- thermoelectric materials generate electric power from temperature differences
- energy of sun and combustion engines lost as heat



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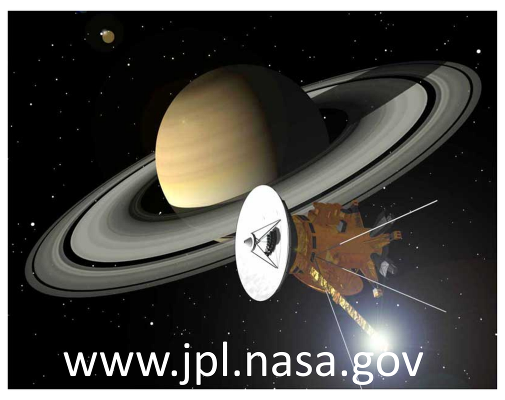
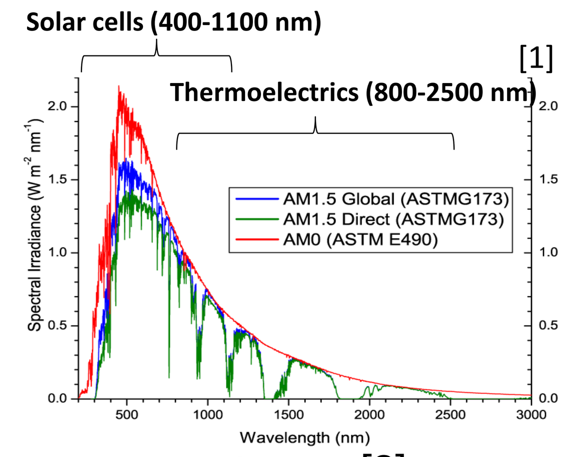




- state-of-the-art: inorganic semiconductors, e.g. Bi_2Te_3[2]
  - high working temperatures (~ 200° C)
  - cost- /energy-intensive processing
  - rare, possibly toxic materials (Bi, Pb,..)
- new hybrid approach: nanoparticles influence thermoelectric properties of polymer
  - conducting polymers: abundant, cheap, environment-friendly
  - water-based thin-film processing
  - usable at lower temperatures (30° C- 100°C)

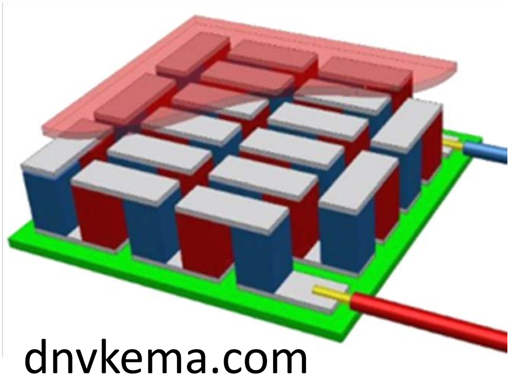
2. Thermoelectric materials

General working principle:

- Seebeck effect: Temperature gradient induces flow of majority carriers (electrons or holes) from hot to cold side → thermovoltage
- figure-of-merit

$$ZT = \frac{\sigma S^2 T}{\kappa_{el} + \kappa_{ph}}$$

σ = electrical cond.
S = Seebeck coeff.
κ = thermal cond.



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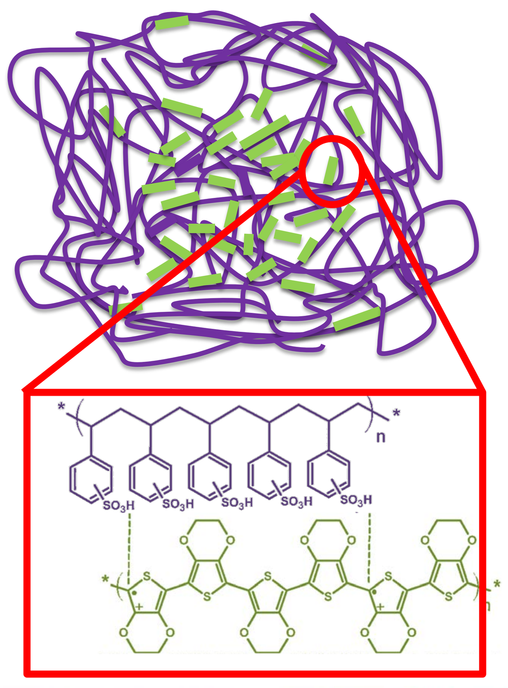
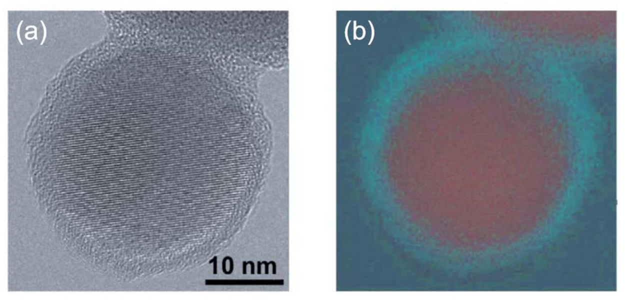
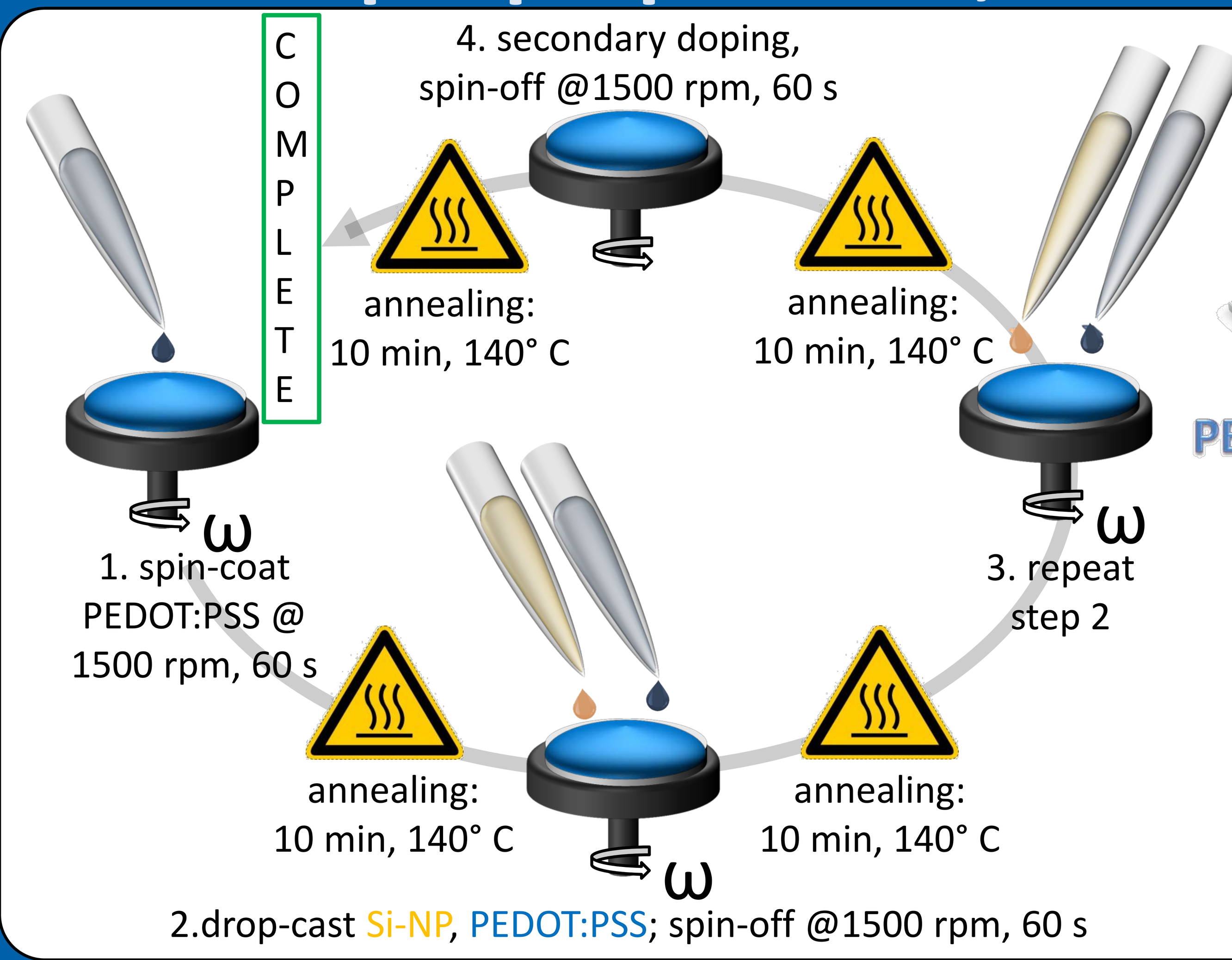


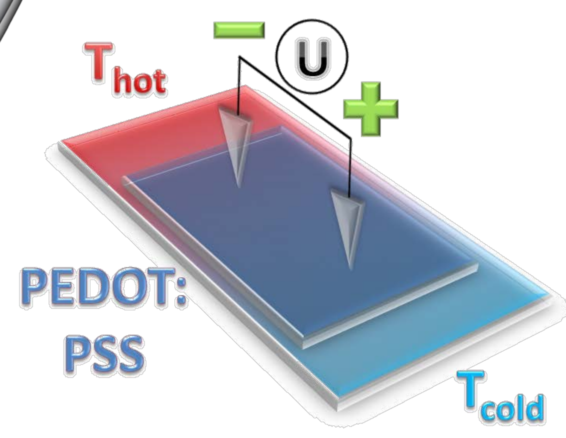
- PEDOT:PSS: hole-conducting polymer blend, tunable morphology, water-processable → film preparation by successive spin-coating of PEDOT:PSS and Si-NP
- Si-Nanoparticles[3] inhibit heat transport by phonons through scattering → reduction of κ_{ph}



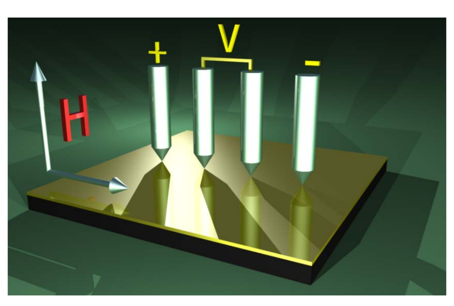
3. Sample preparation, characterization



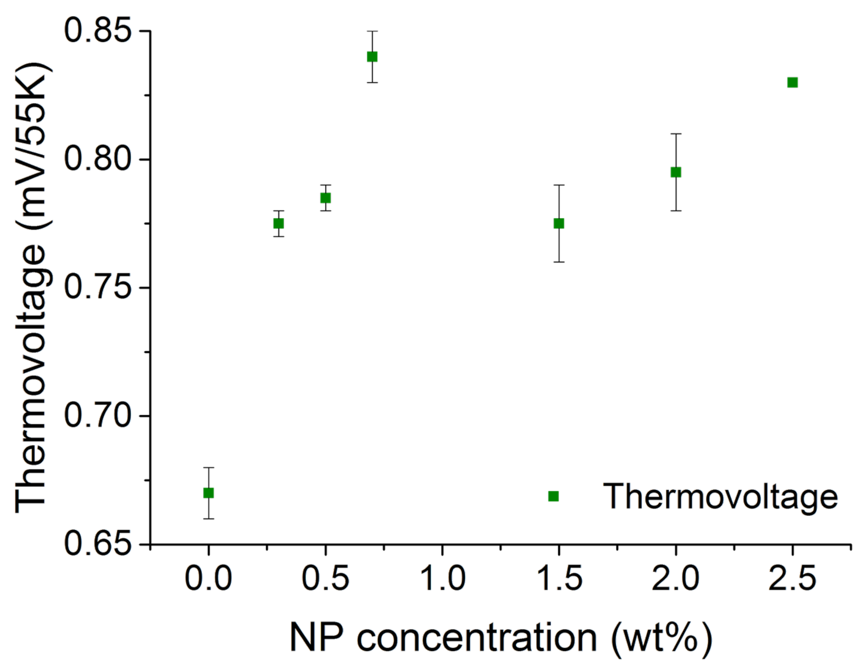
Thermovoltage measurement:

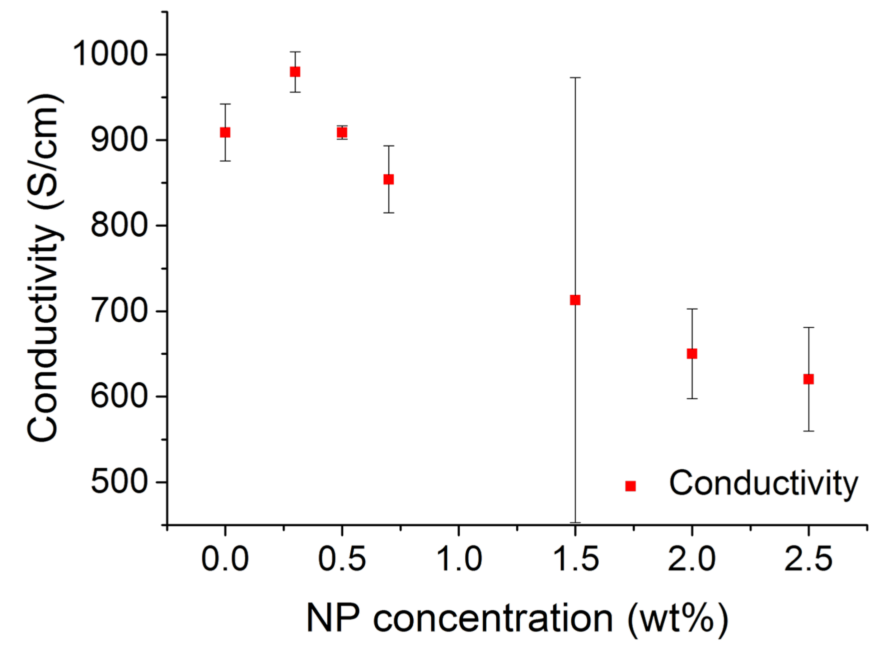


4-terminal sensing:

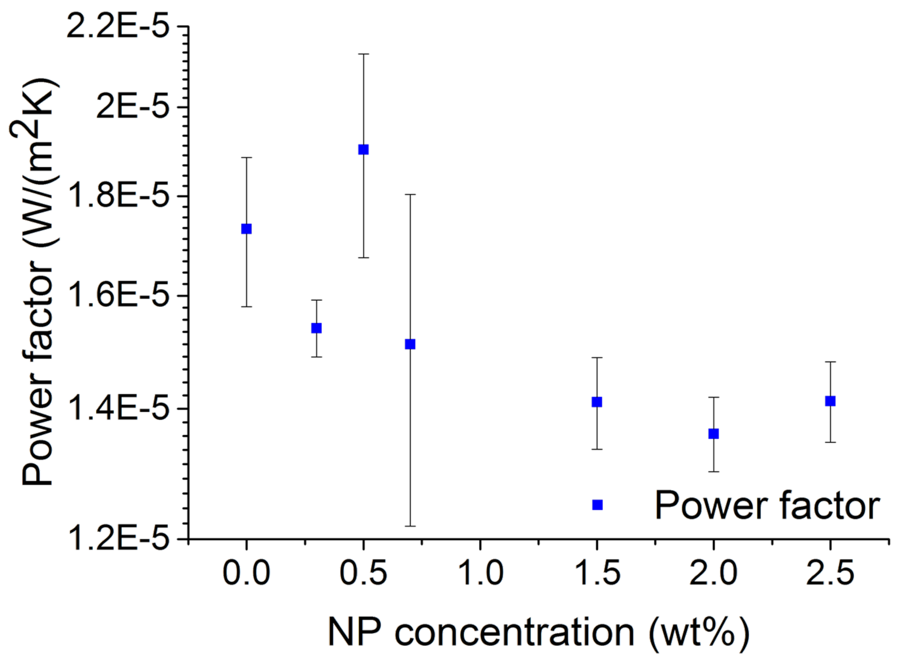


4. Influence of nanoparticles





- increased thermovoltage with increasing conc. of nanoparticles
- maximum for conductivity, decreasing for high conc. of NP
- optimum power factor for 0.5 wt% NP → optimum conc. of NPs

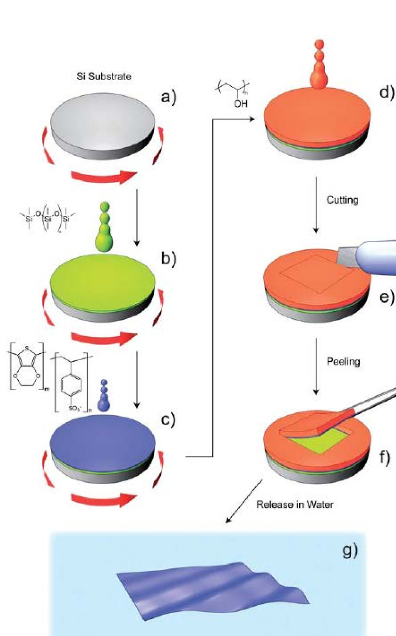


5. Thermal conductivity measurement

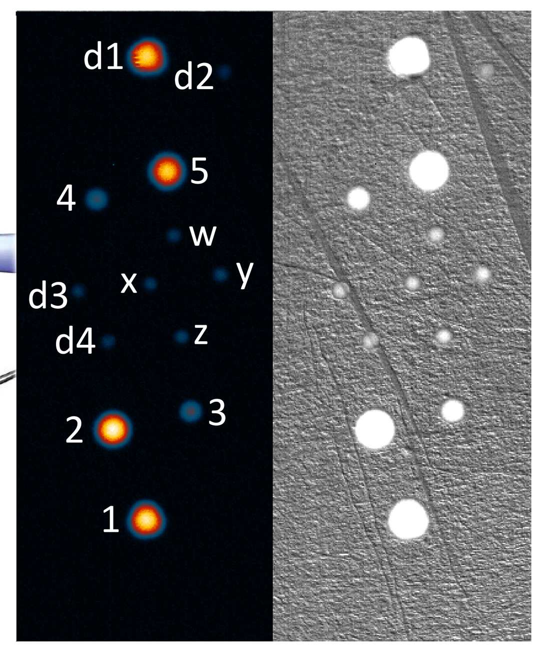
- removal of PEDOT:PSS film from substrate by using PDMS as basis, supported by PVA[4]
- release in DI-H_2O onto steel/Al sample holder
- illumination with LED, detection with IR camera
- strong influence of hole size and lock-in frequency
- κ for low frequencies around 0.5 W/K·m
- calculation of figure-of-merit possible:

$$ZT = \frac{\sigma S^2 T}{\kappa_{el} + \kappa_{ph}} \approx 0.064$$

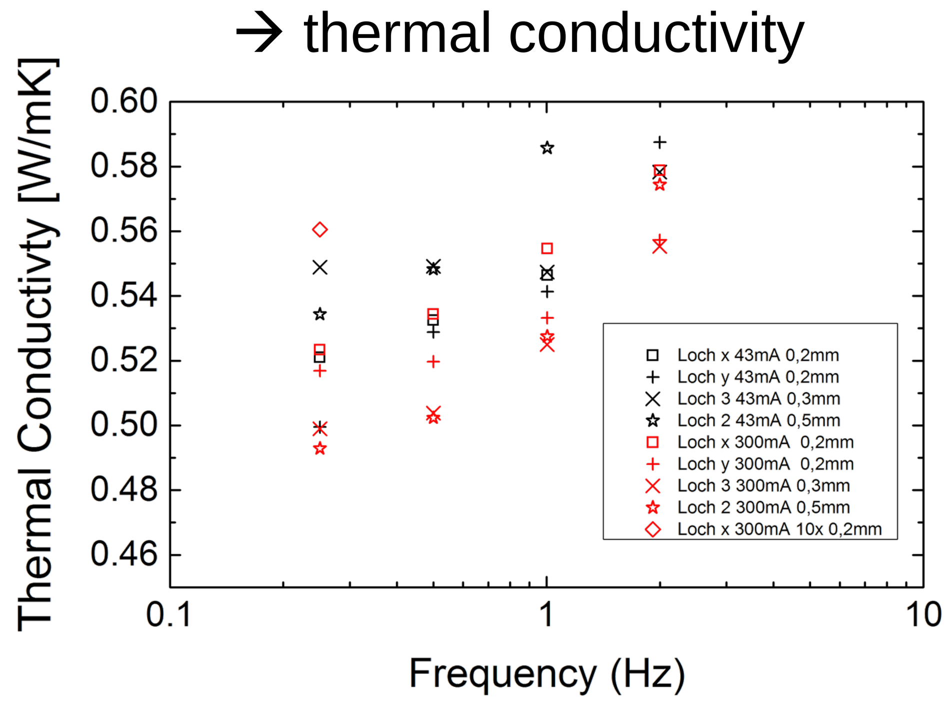
free-standing PEDOT:PSS[4]



Lock-in thermography: Amplitude Topography



evaluation of data → thermal conductivity



6. Conclusion

- dependence of thermovoltage and electrical conductivity on NP concentration → power factor optimal at 0.5 wt% NP
- implementation of procedure for free-standing PEDOT:PSS nanofilms
- lock-in thermography: $\kappa \approx$ 0.5 W/K·m
- calculation of figure-of-merit: ZT ≈ 0.064

References

[1] pveducation.org
[2]Zhang *et al.*, *Adv. Mat.*, **2014**
[3] Andre Stegner, PhD thesis, **2010**
[4] Greco *et al.*, *Soft Matter*, **2011**

Acknowledgements

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