Thermoelectric transport measurements of Carbon Nanotube:Polymer Composites

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Motivations

*High efficient thermoelectric generators convert heat into electricity.
*Thermoelectric is a green and sustainable energy.
*Cheap, large-scale and non-toxic TE materials for the future. [1]
*s-SWCNTs has a very high Seebeck due to the van Hove singularities. [2]
*s-SWCNTs is promising with a PF of ~700$\mu W/mK^2$ and ZT of 0.12.[2]
------Boost ZT by electron-crystal-phonon-glass concept.
------Insightful understanding of the charge transport physics is needed.

$$\eta = \frac{T_h - T_c}{T_h} \frac{\sqrt{1+zT_m}-1}{\sqrt{1+zT_m}+T_c/T_h}$$

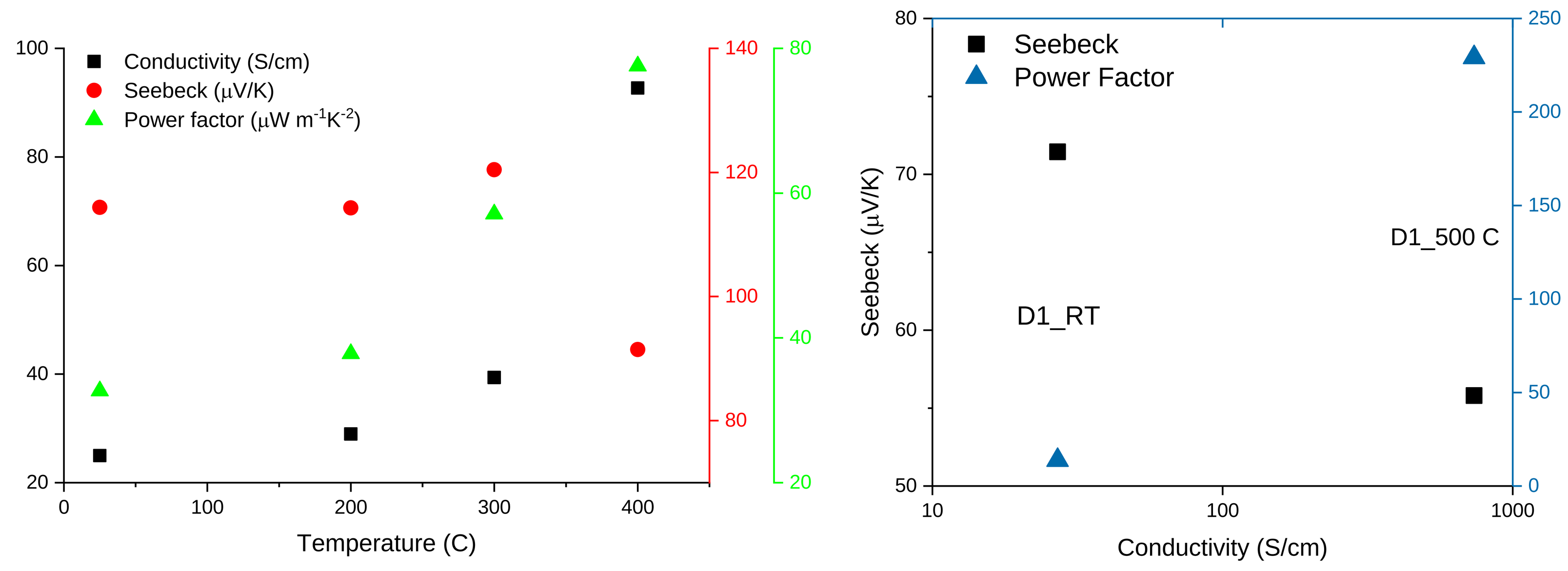
$$ZT = \frac{S^2 \sigma T}{\kappa}$$

High ZT materials needed

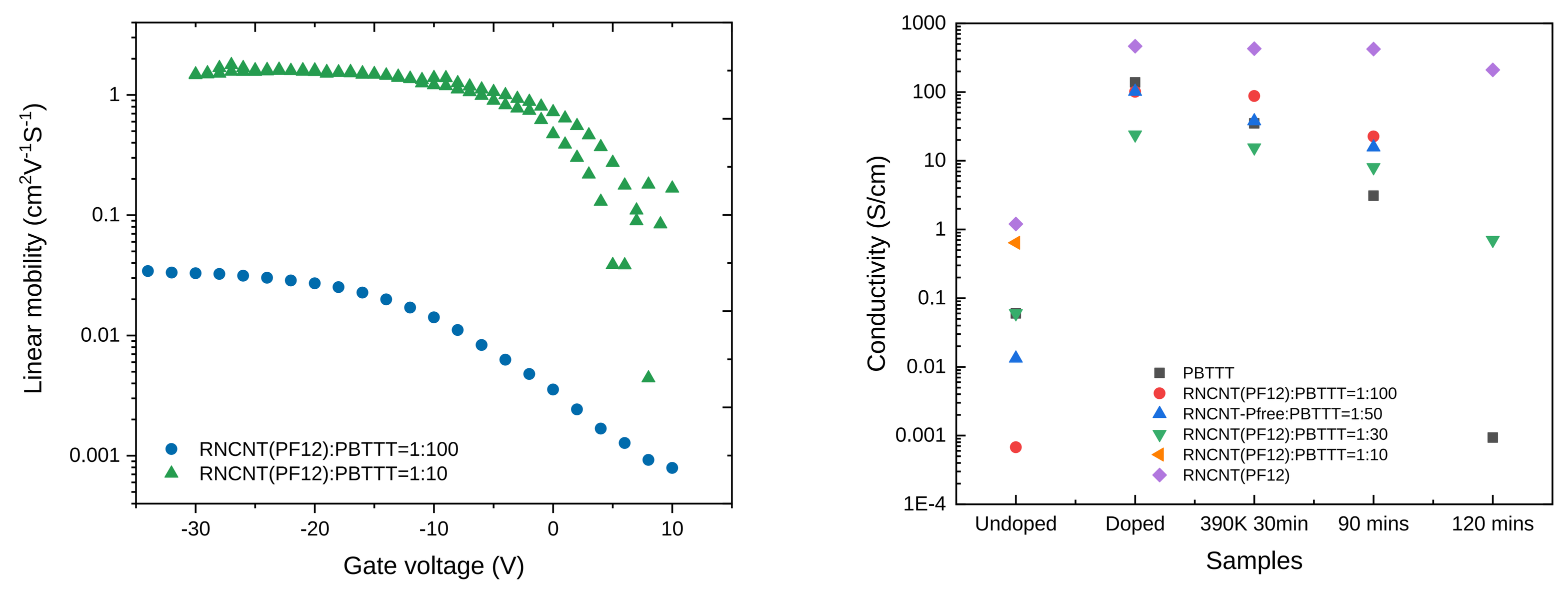
CNTs:Polymer composites

TE properties

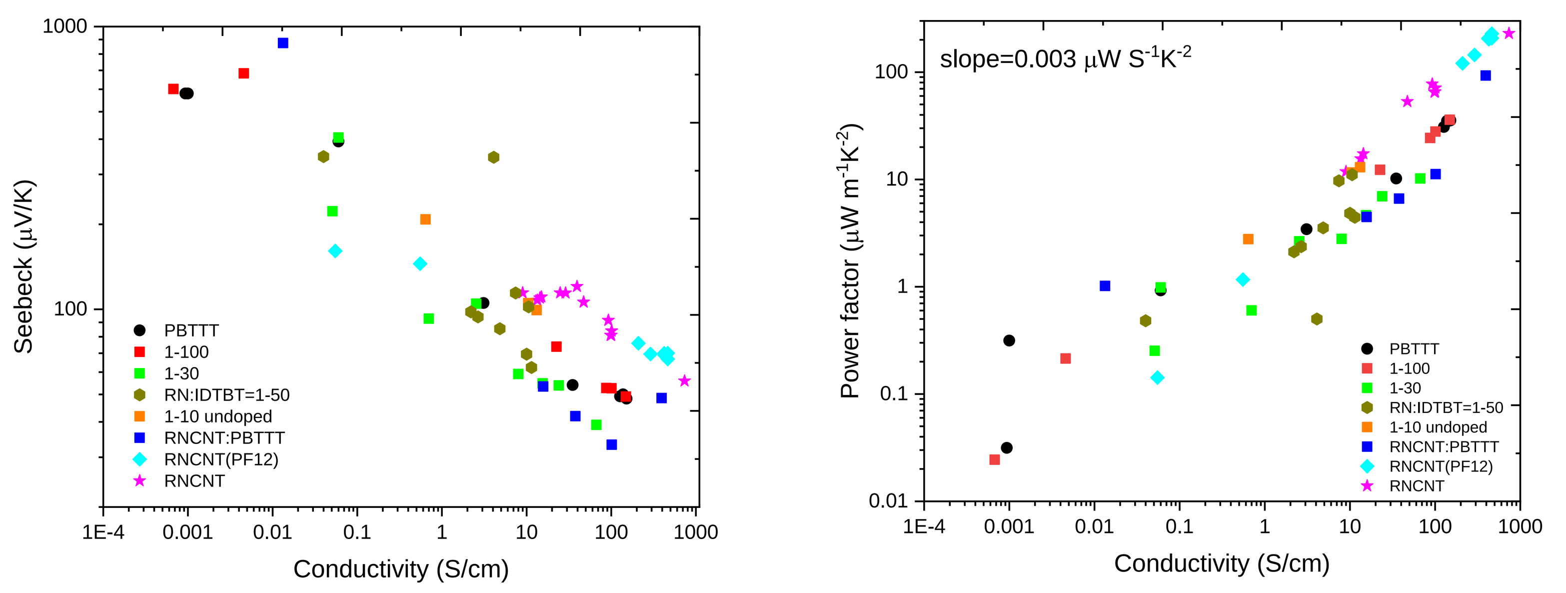
Enhance the power factor of CNT network by removing the insulating sorting polymers via thermal annealing.



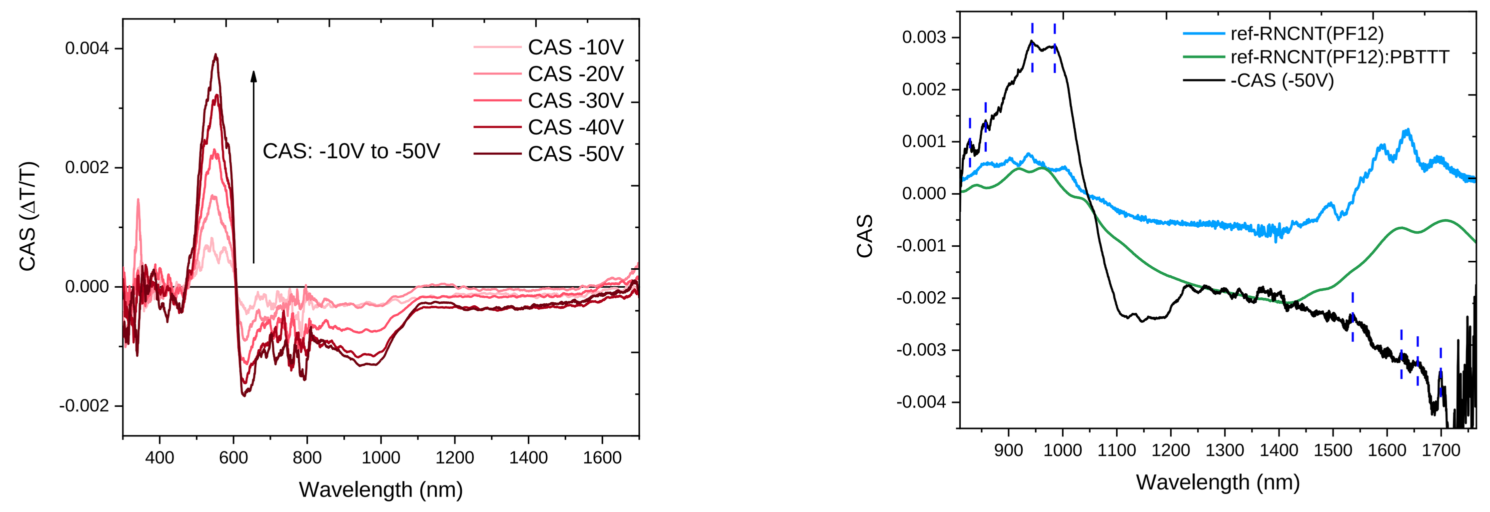
The mobility and doping thermal stability of RNCNT:PBTTT composites increase with a higher loading of CNTs.



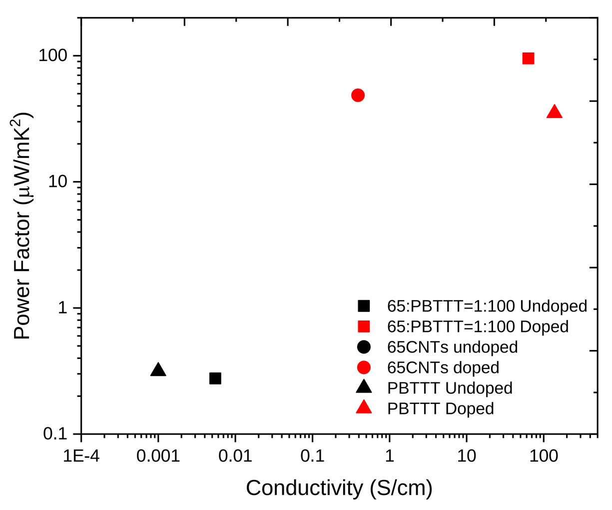
Undoped polymer-free RNCNTs shows the highest PF of 240 $\mu W/mK^2$



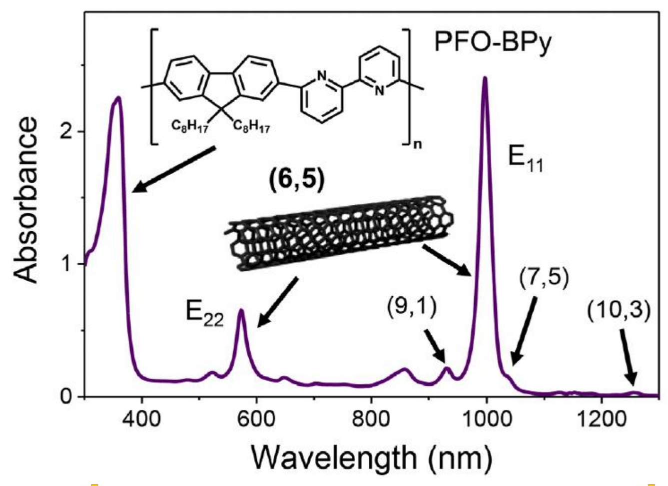
CAS spectrums reveal that charges transport through PBTTT and CNTs.



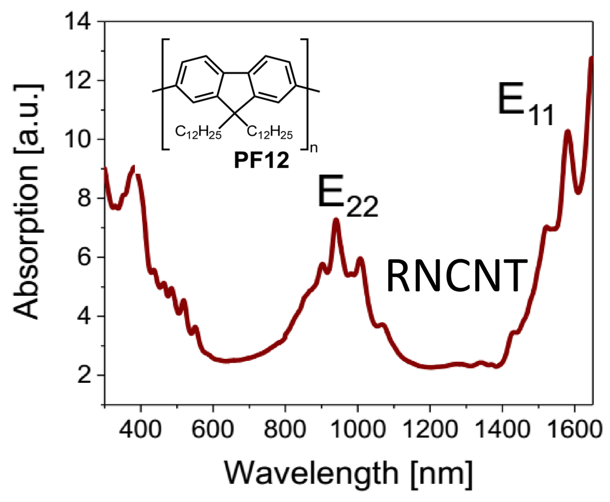
(6,5)CNT(PFO-BPy):PBTTT=1:100 composite outperform individual component due to the large Seebeck of (6,5)CNTs.

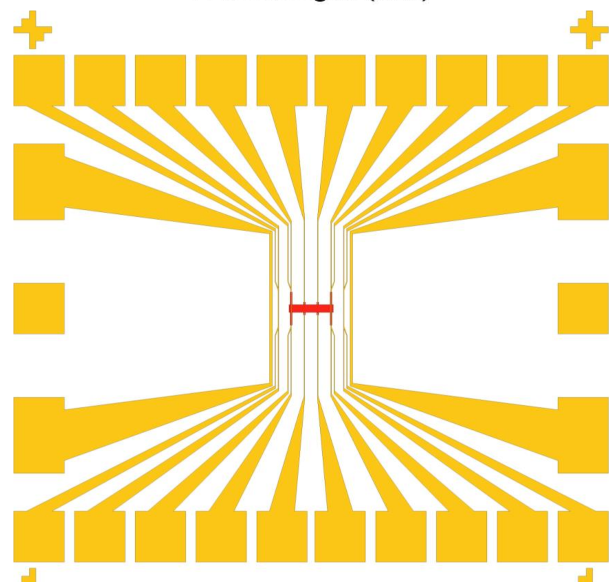


Experiments

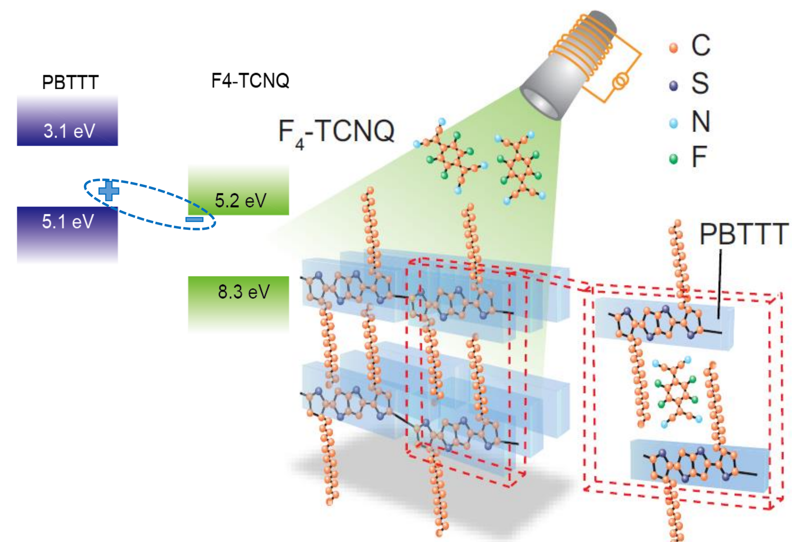


[3]





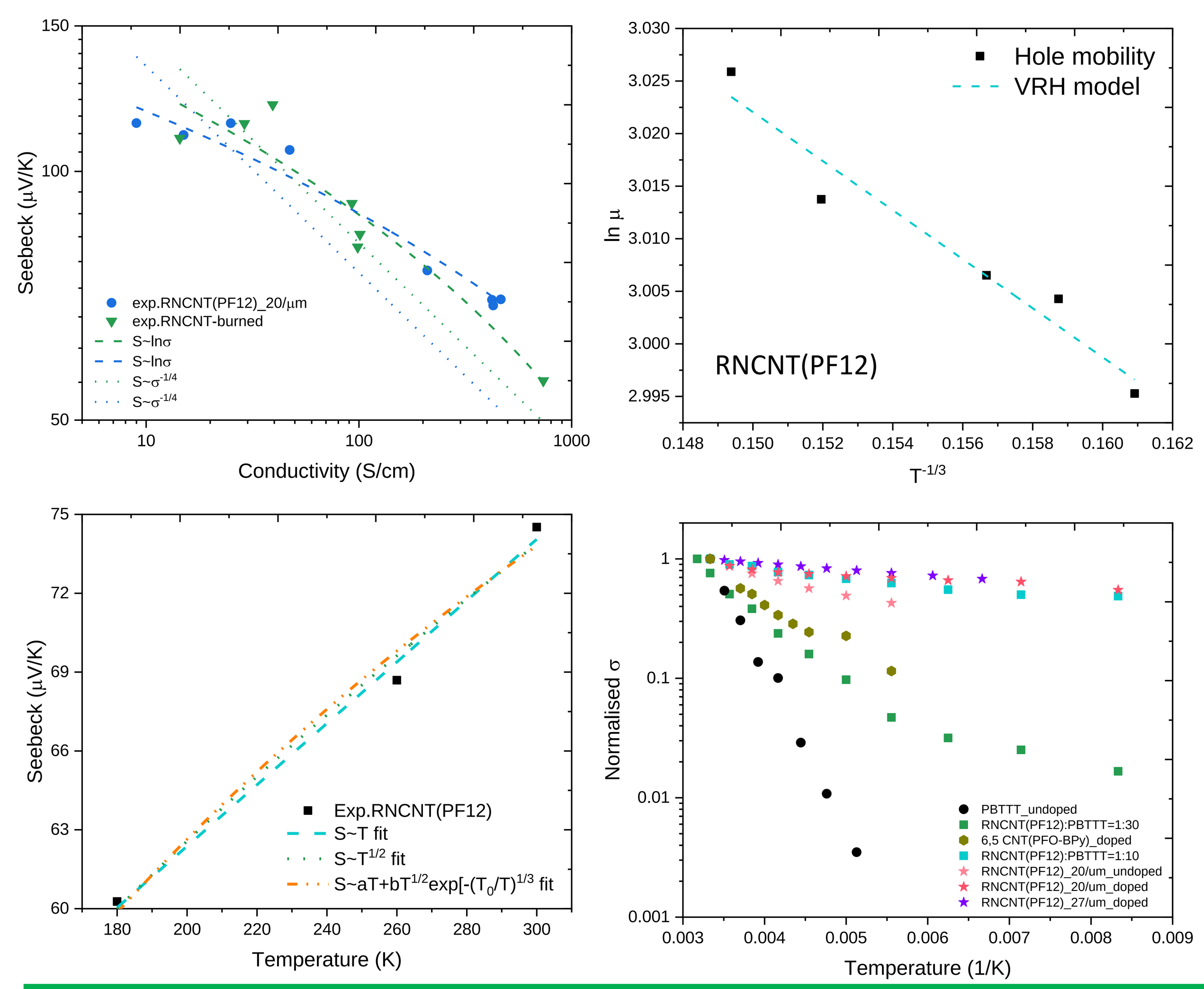
Multi-functional device [4]



Evaporation doping [5]

Charge transport physics

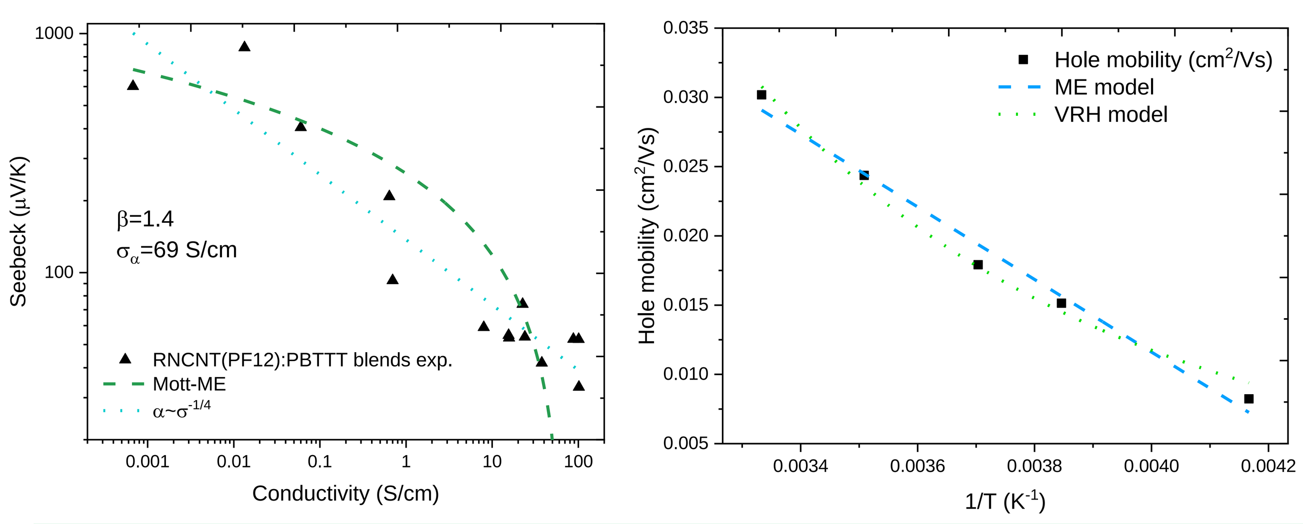
Charge transport physics of neat s-SWCNT network



The charge transport physics of neat s-SWCNT network can not be simply fitted with the variable-range hopping model, mobility edge, fluctuation induced tunneling, Kaiser's and Snyder's models.---**A new model is required**.

From $S(\sigma), \mu(T), S(T)$ and $\sigma(T)$, the effective mass, Fermi level, mobility and energetic landscape are revealed. ---**uncover the transport physics.**

$S(\sigma)$ and $\mu(T)$ of RNCNT:PBTTT composites



The charge transport of composite material is Arrhenius-like behavious which is better modelled by the VRH model. [6]

The transport physics in the CNT-polymer interface need to be understood.

Conclusions

1. **The doped neat CNT network and CNT:PBTTT polymers exhibit promising TE properties.**
2. **Removal of sorting polymers improves the PF of CNTs.**
3. **Higher CNT network density increases the PF and doping thermal stability.**
4. **The electron-crystal-phonon-glass concept could be realised.**

Outlook

* Measure the thermal conductivities of CNTs and CNT:polymer composites.
* Modify the charge transport in the tube-tube junction of the s-SWCNT network.
* Understand the charge transport in the CNT-polymer interfaces.
* Uncover the doping mechanism and structure-property relation.

References

[1] Crispin et al., *Nature Energy*, 1, 16037, (2016)
[2] MacLeod et al., Energy Environ. Sci., 10, (2017)
[3] Rother et al. *Advanced Electronic Materials* 3.8 (2017)
[4] Statz et al. *Communications Physics* 1.1 (2018)
[5] Kang et al., *Nat. Mat.* 15, 896, (2016)
[6] Venkateshvaran et al., *Nature*, 515, 7527 (2014)

Acknowledgements

OE – FET group