Optimization of Thermoelectric Properties of Carbon nanotube (CNT) veils by Defect Engineering

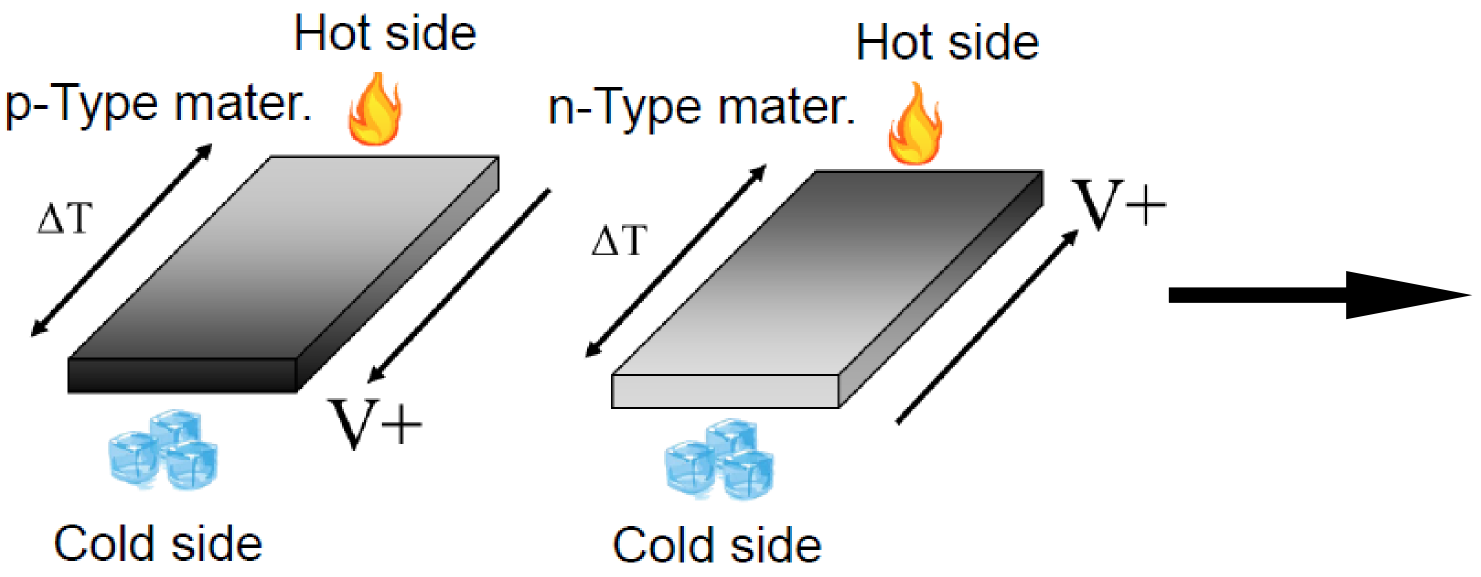
Speaker: Chongyang Zeng

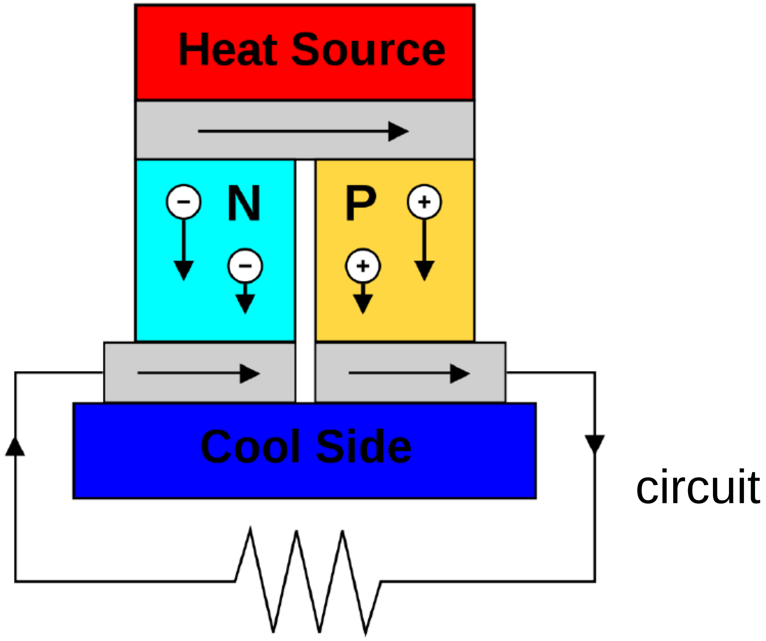
Supervisor: Emiliano Bilotti, Han Zhang

1 Introduction

Thermoelectrics(TE) for Energy Conversion

Seebeck effect (Heat energy to electrical energy)





Model of TE Generator (π-Type)

1 Introduction

TE Performance of Materials

Evaluation of Thermoelectric Performance of Materials

- Thermoelectric Figure-of-merit

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

S: Seebeck coefficient

σ: Electric conductivity

T: Absolute temperature

κ: Thermal conductivity

Requirement for practical applications: ZT = 1

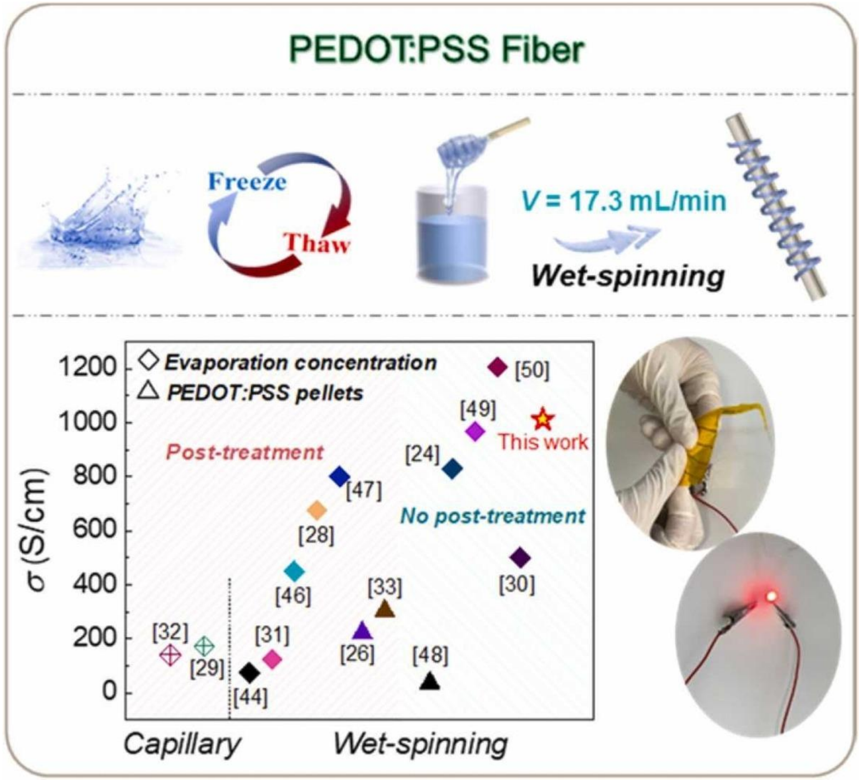
- Power Factor

$$PF = S^2\sigma$$

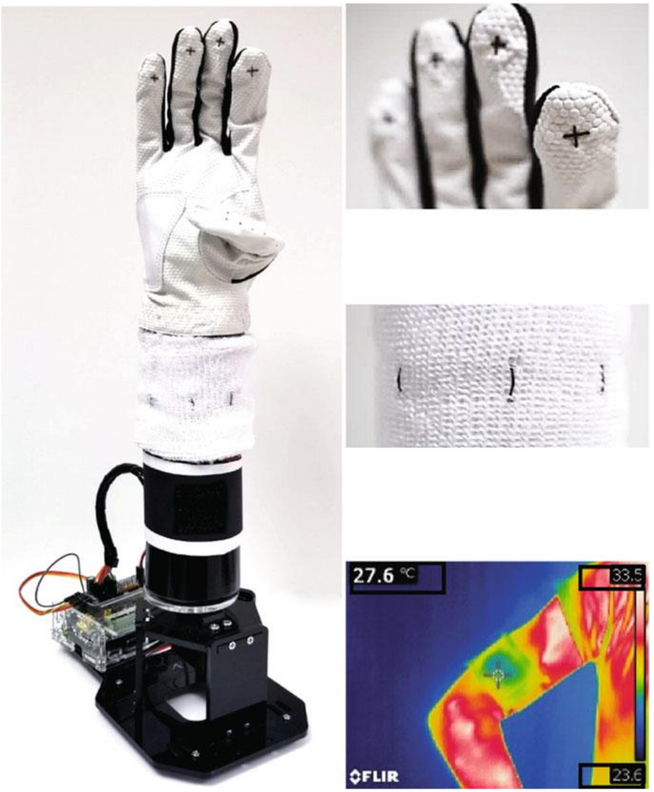
high ZT
→ high efficiency
→ application

1 Introduction

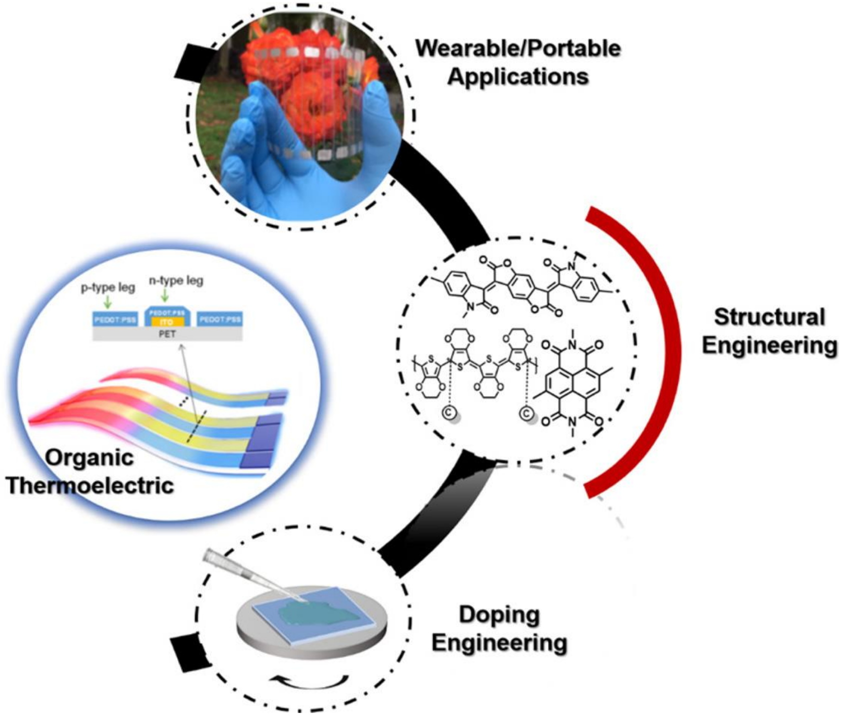
Organic thermoelectric materials



Nano Energy 102,107678 (2022)



Nature communications, 1, 1-8 (2020)



Macromol. Res, 28(6), 531-552 (2020)

Advantages

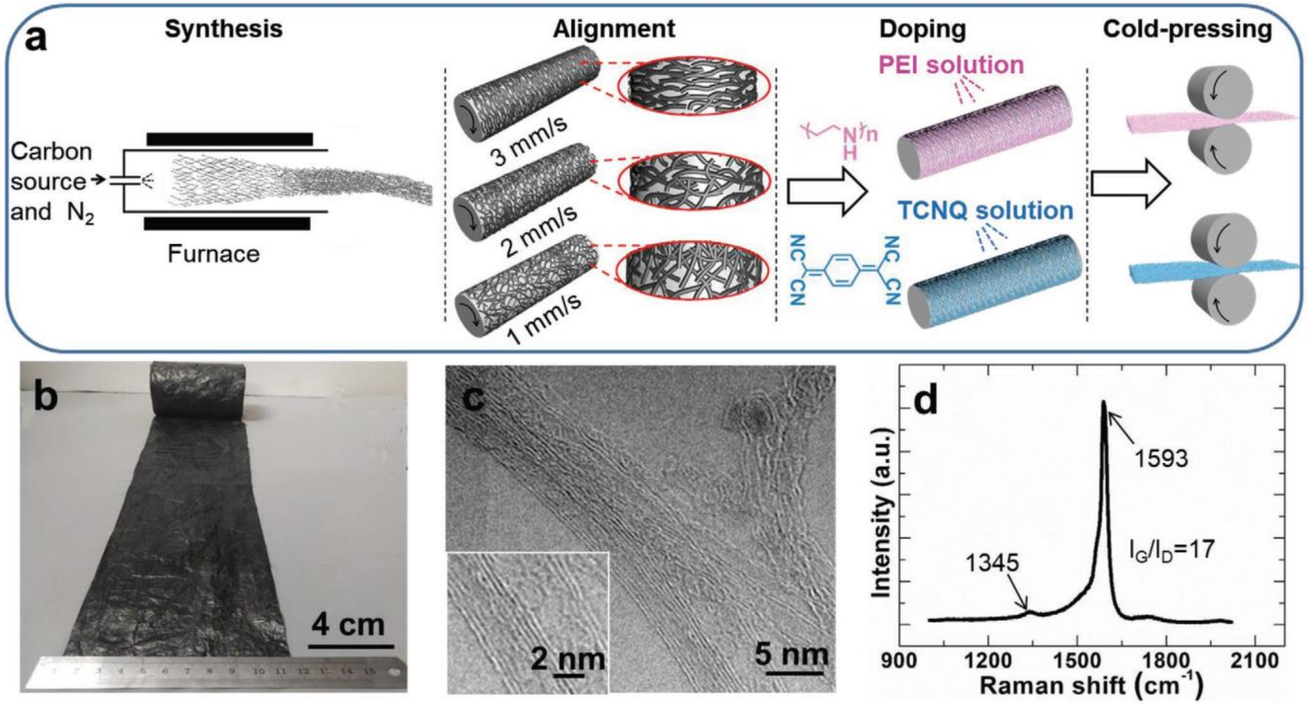
Flexible

Easy processing

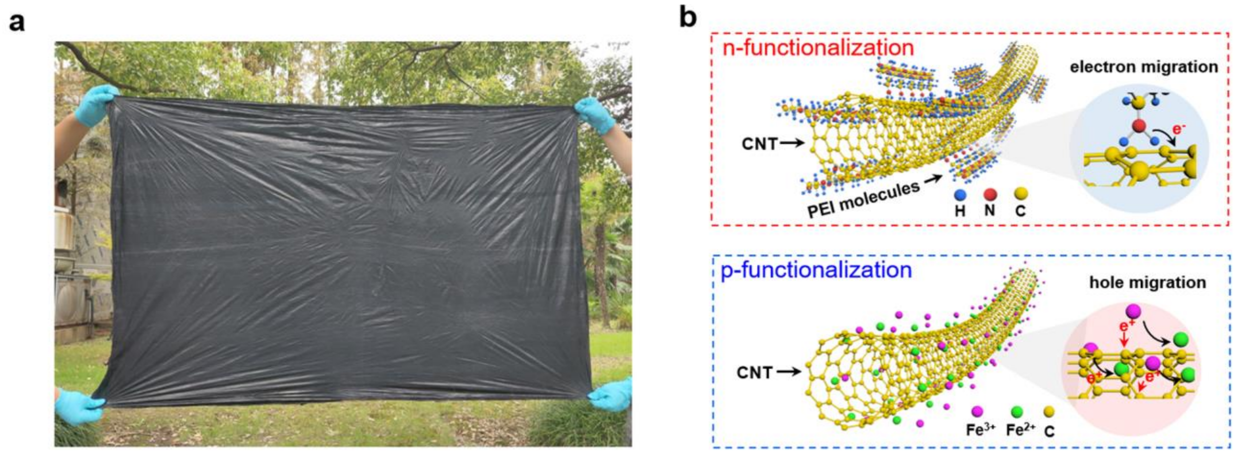
Scalable

Non-toxic

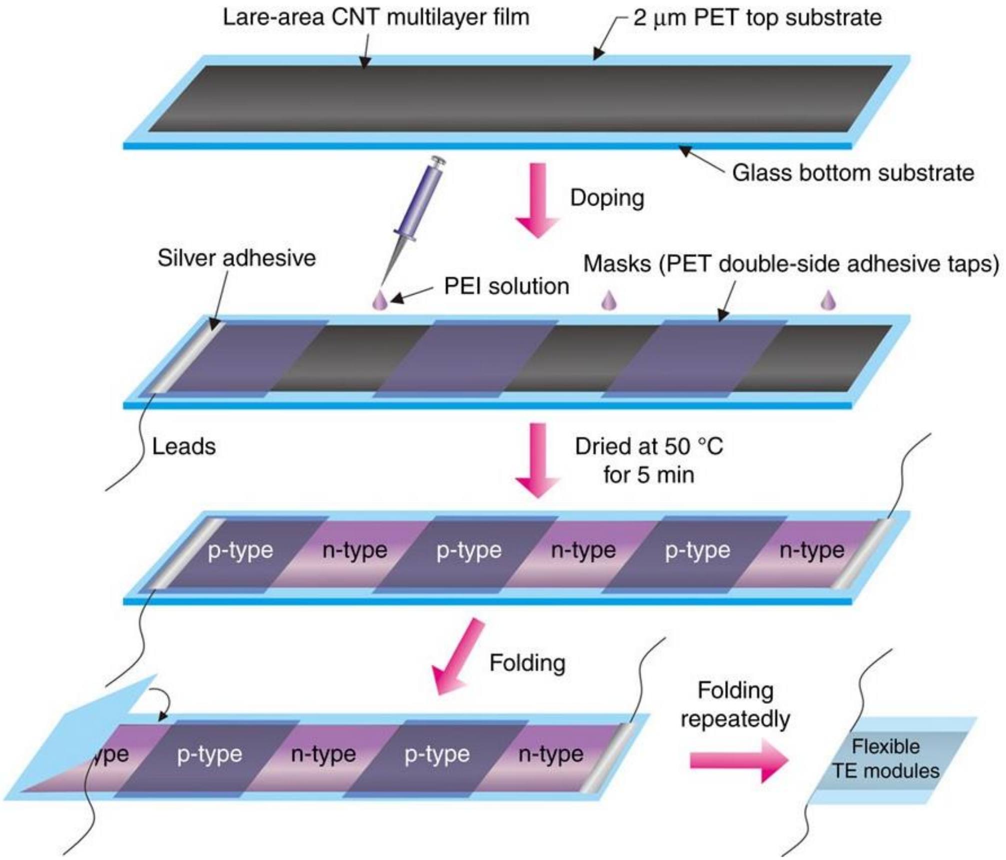
1 Introduction



Adv. Funct. Mater, 32, 2203080 (2022)



Nano Energy 89 (2021) 106487

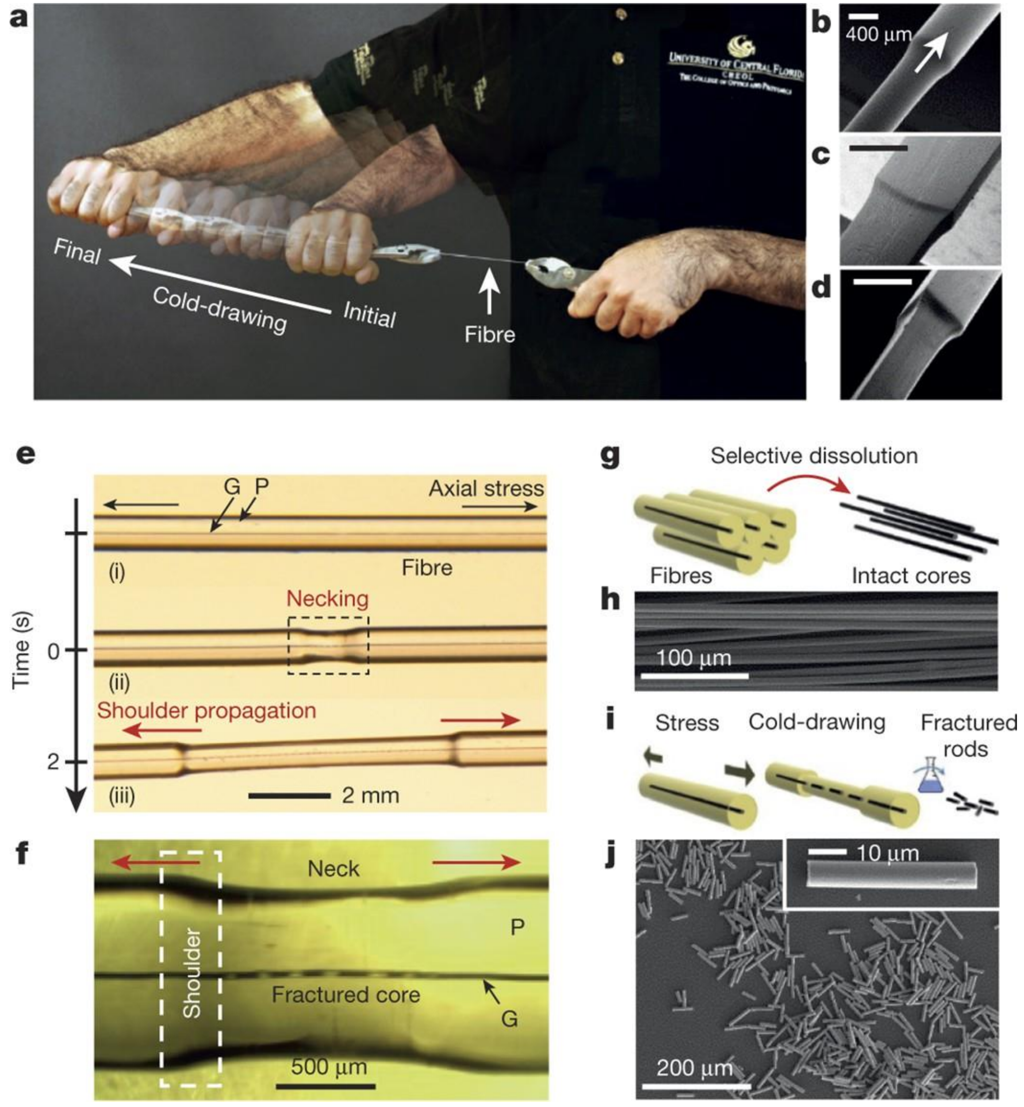


Nature communications, 8, 1-9 (2017)

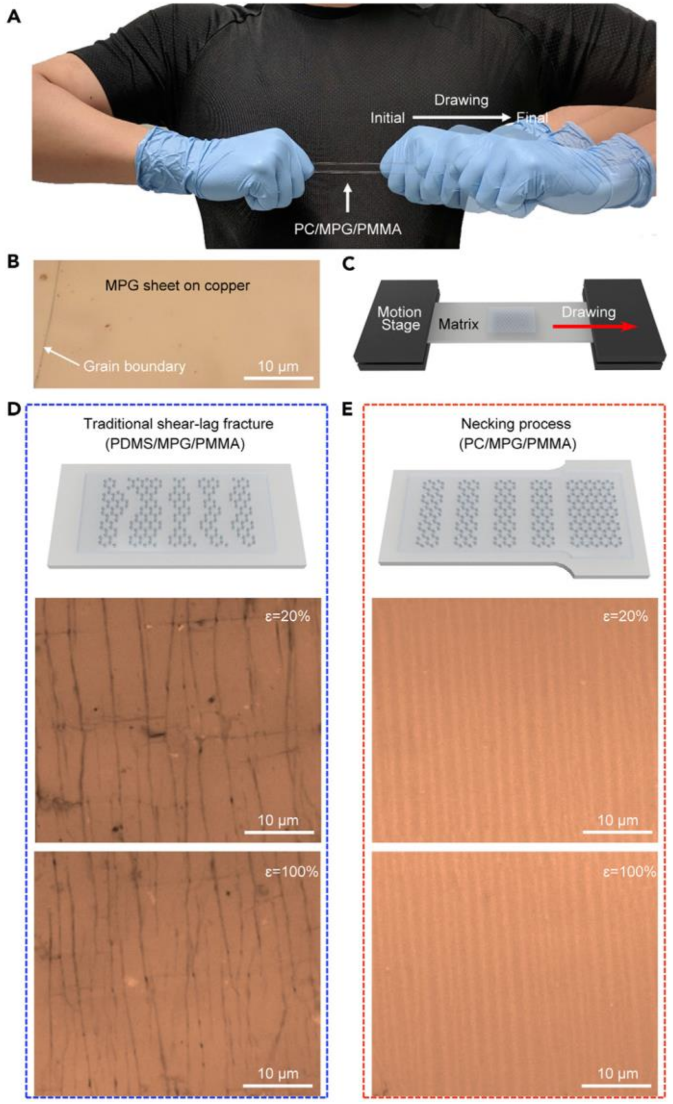
- Thermoelectric Figure-of-merit

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

1 Introduction



Nature, 534, 529–533 (2016)

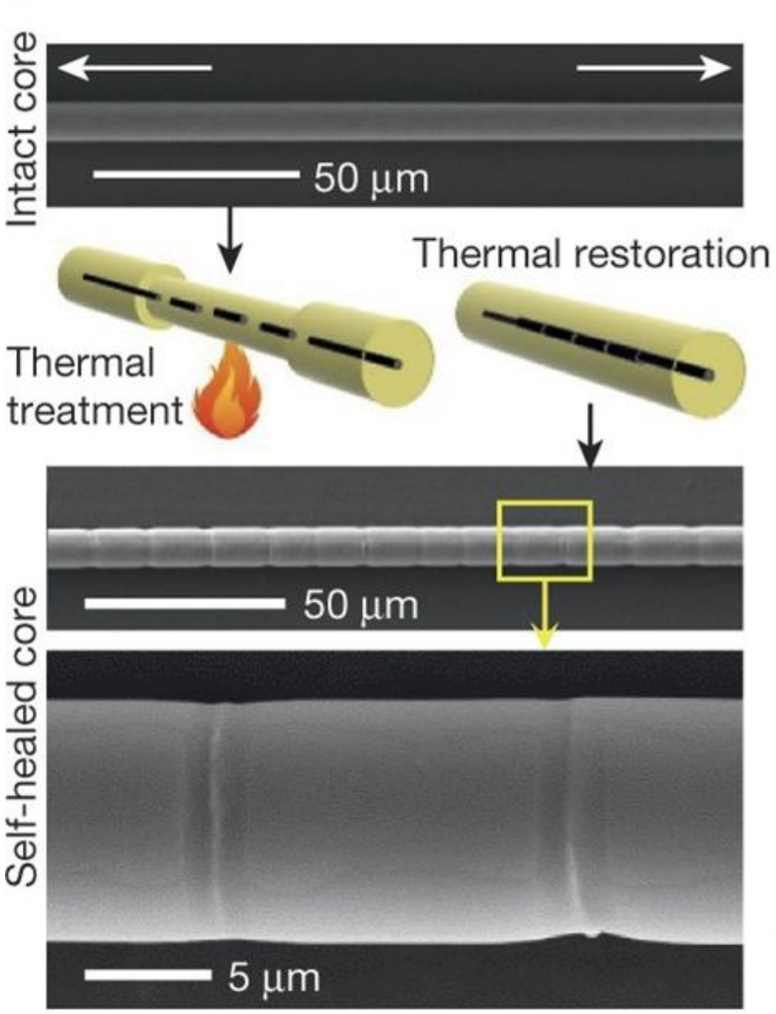


Matter 2, 666–679 (2020)

Core:
Silicon
Gold
Glass
Silk
Ice
Germanium
Polystyrene
Biodegradable polymers
Monolayer graphene

Polymer cladding:
Polysulfone (PSf)
Polyethersulfone (PES)
Polycarbonate (PC)
Polyetherimide (PEI)
Cyclic olefin polymer (COP)
Poly (methyl methacrylate) (PMMA)

1 Introduction



Nature, 534, 529–533 (2016)

Core fragments can be self-healed/reconnected by thermal treatment

2 Scheme

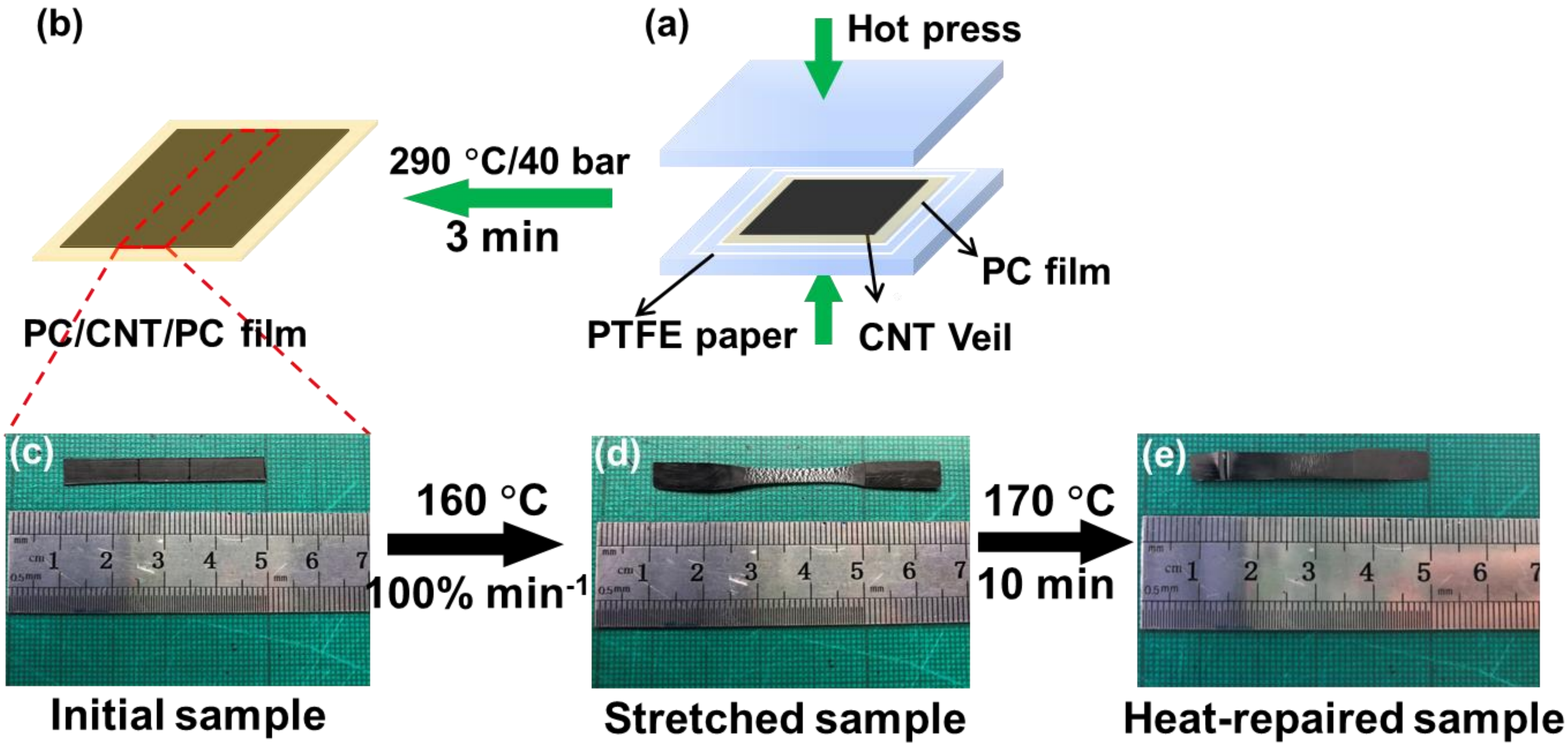
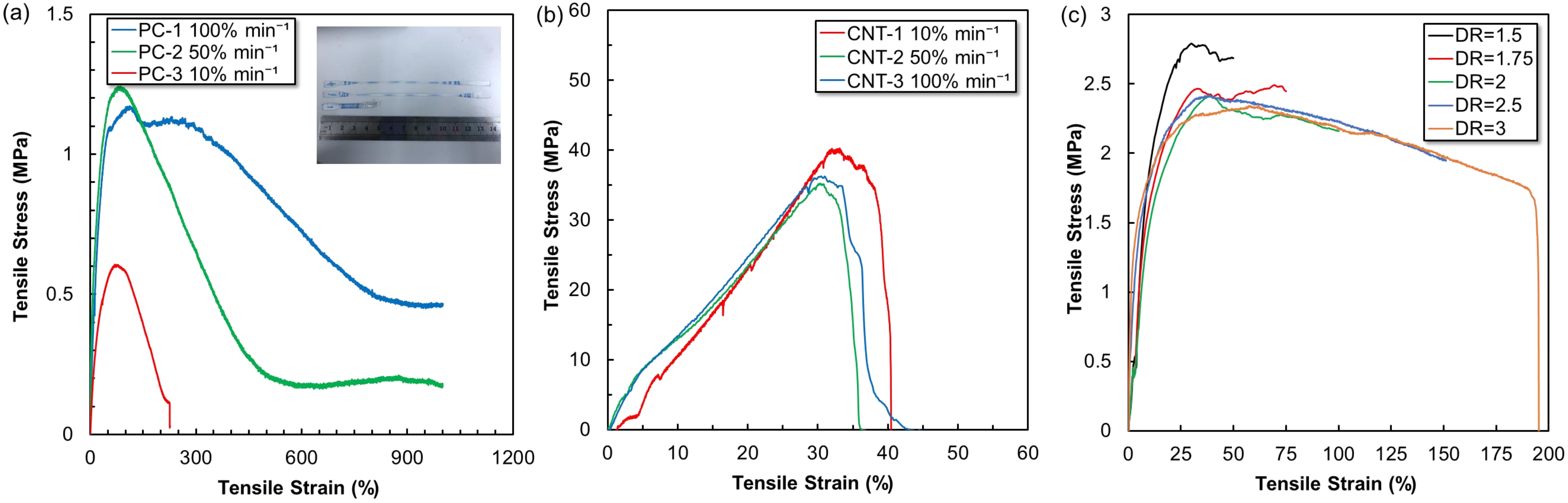


Illustration of the fabrication and stretching treatment of PC/CNT/PC composites

3 Results and Discussion

❑ Mechanical properties at 160 °C



PC film | CNT veil | PC/CNT/PC composite

Load speed of 100 % min^{-1} was chosen for the PC/CNT/PC composites. For PC/CNT/PC, the maximum draw ratio (DR) can reach about 3.

Draw ratio is defined as the ratio between the final length and the original length.

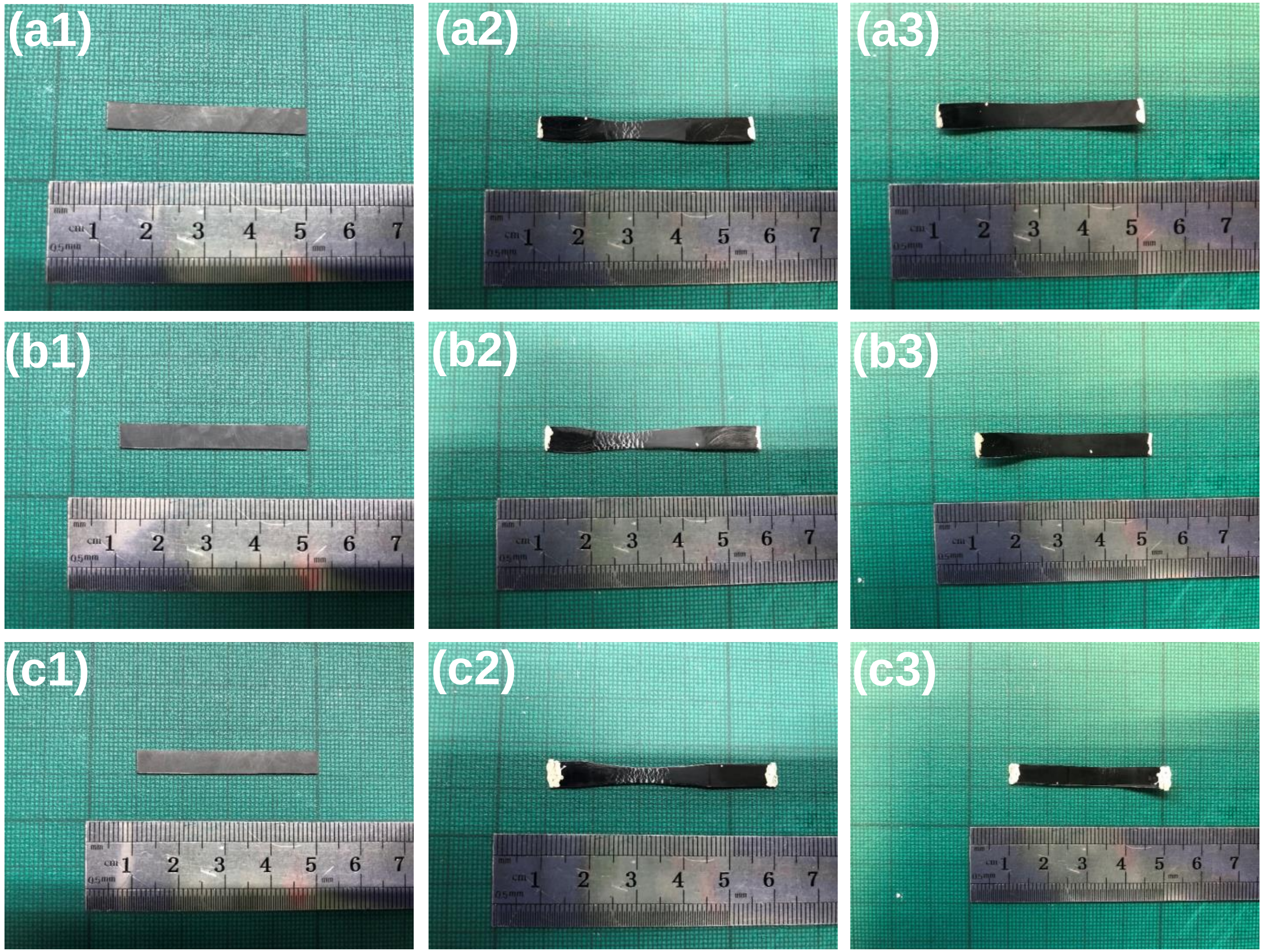
❑ Stretching and heat-repaired results

Initial | Stretched | Heat-repaired

DR=1.5

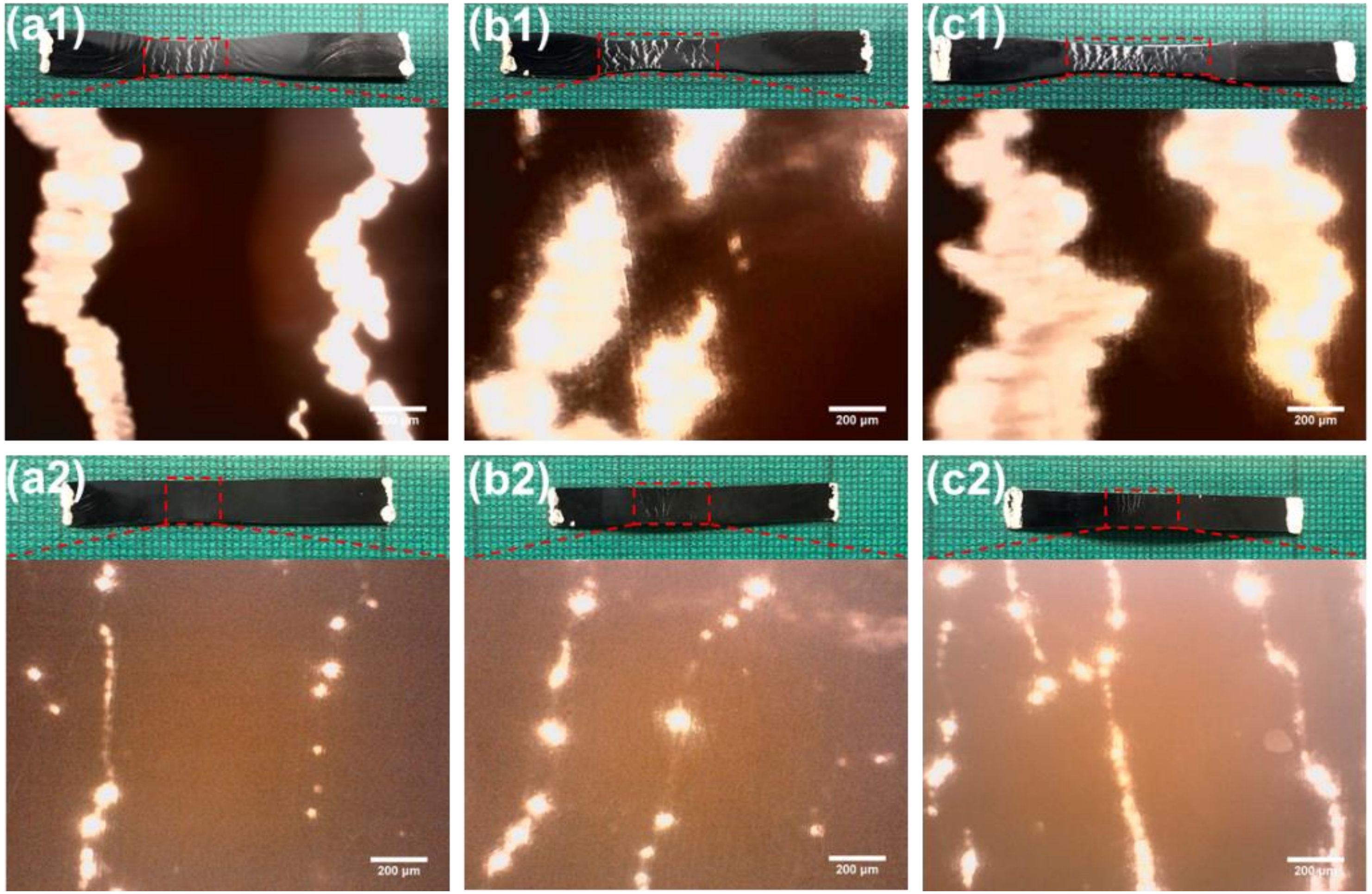
DR=1.75

DR=2



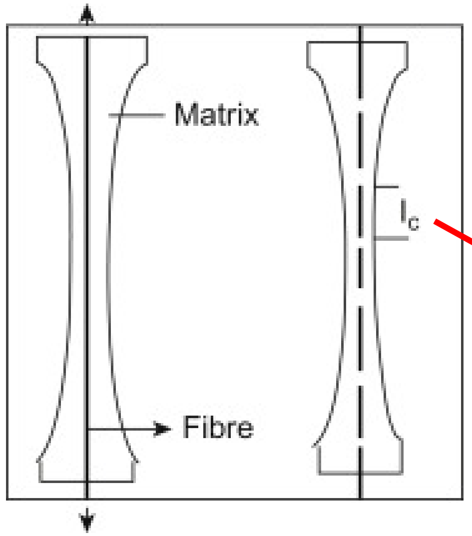
❑ Microscope images of PC/CNT/PC composites

(a)



DR = 1.5 DR = 1.75 DR = 2

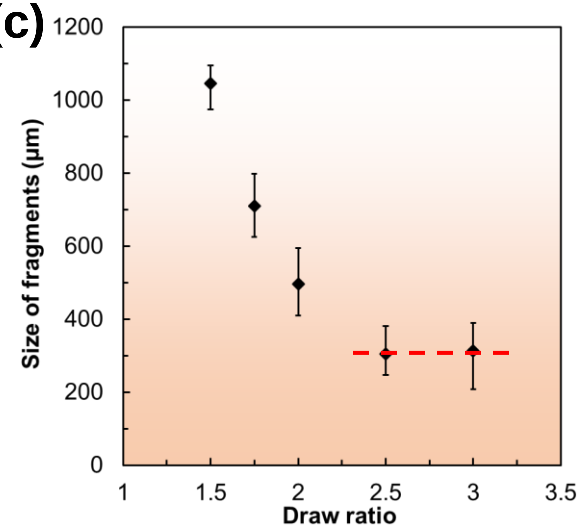
(b)



Comprehensive Composite Materials, 2000

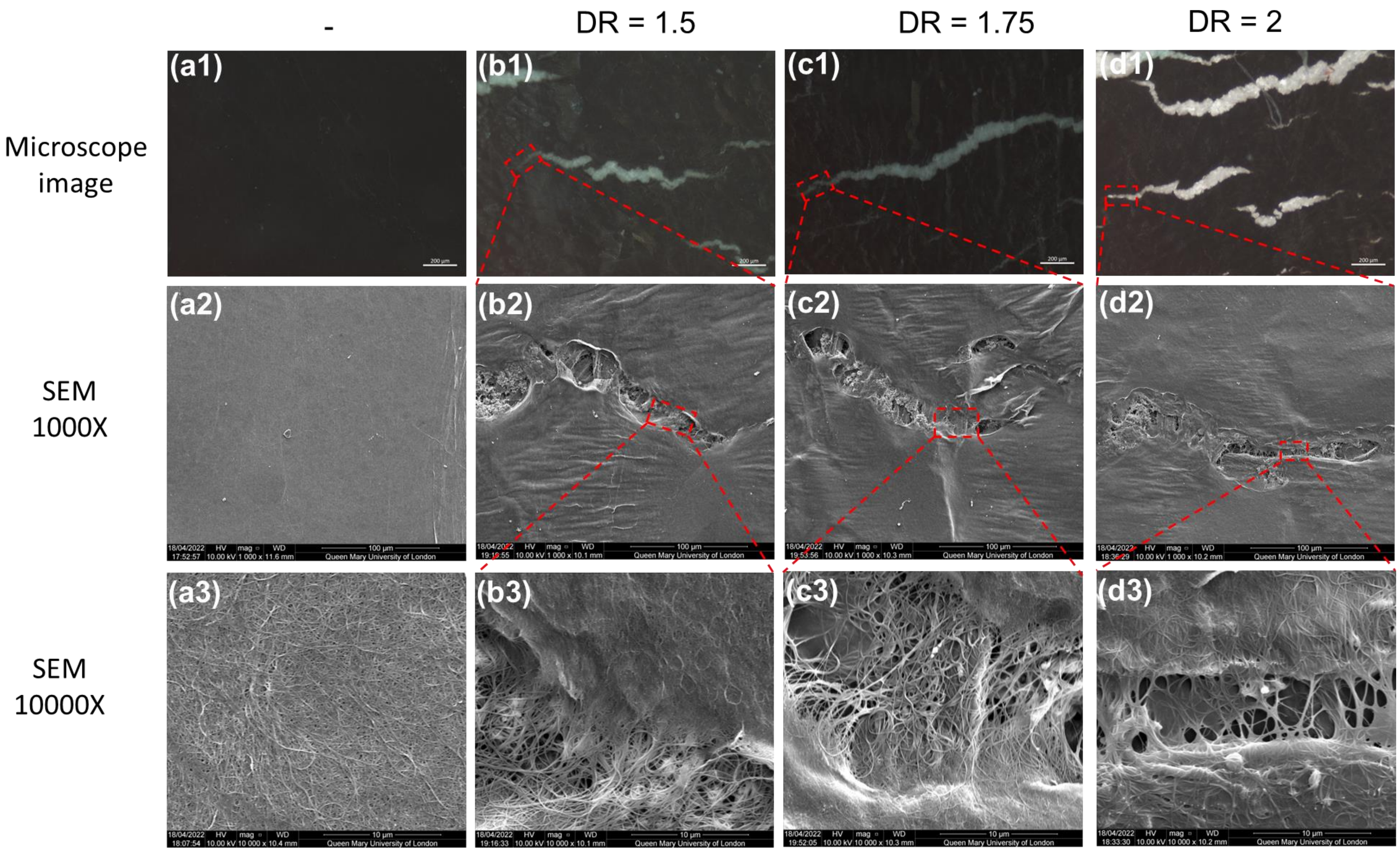
critical length

(c)



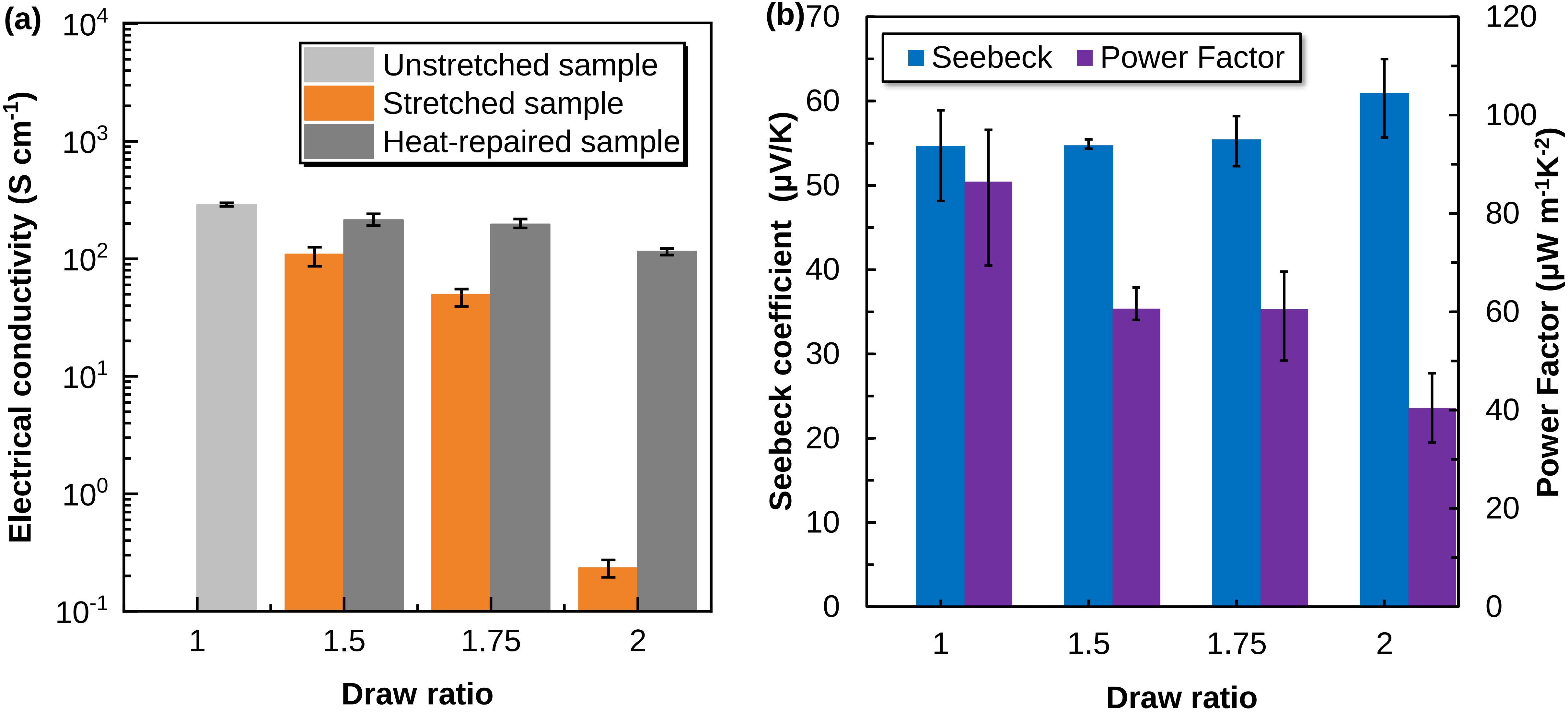
PC/CNT/PC can almost be repaired by thermal treatment and the critical fragment length is about 300 μm.

❑ Microstructures of heat-repaired CNT veils



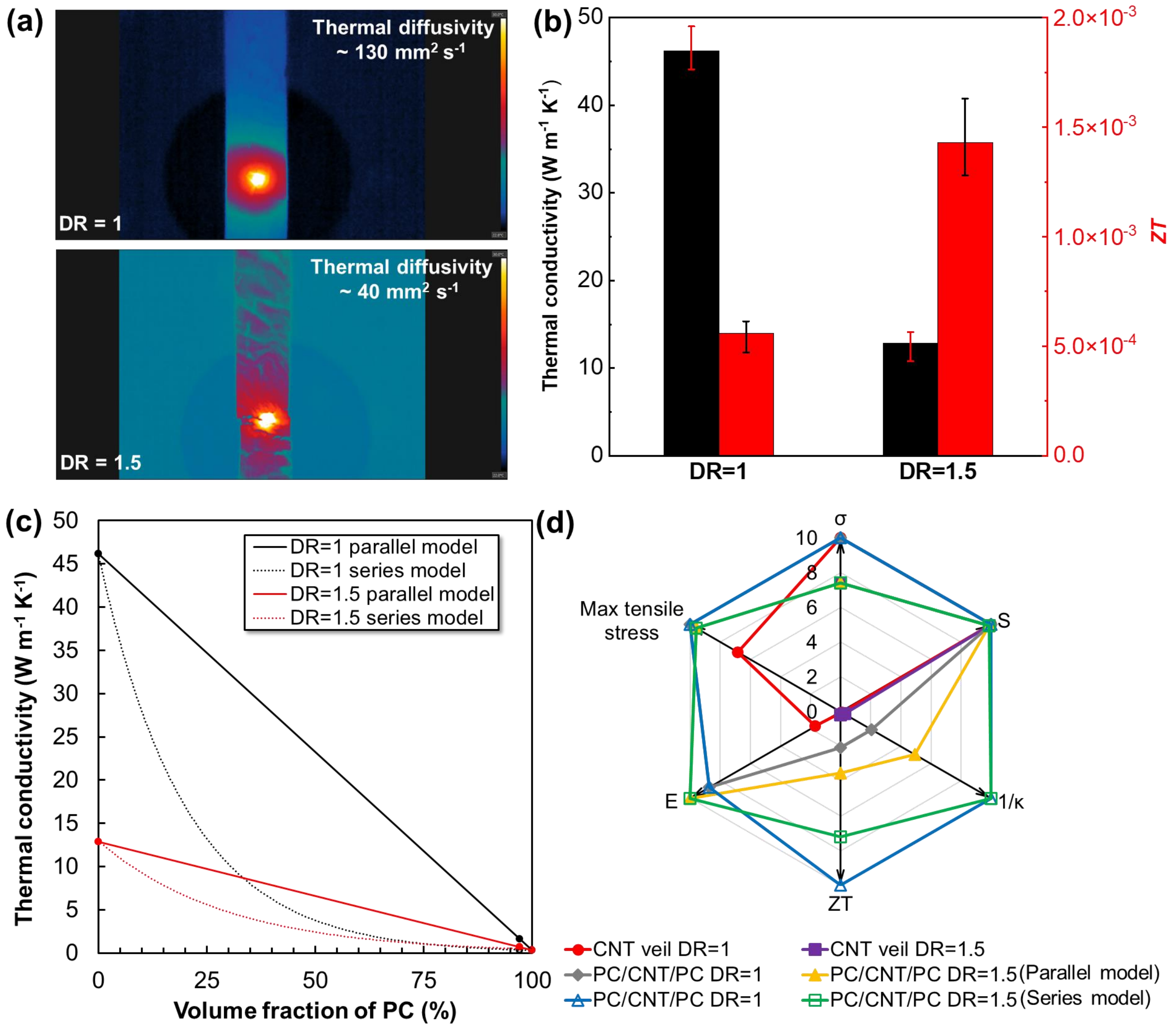
The SEM results show the thermal treatment can reconnect CNT veil fragments electrically but not thermally.

❑ TE performance of PC/CNT/PC composites

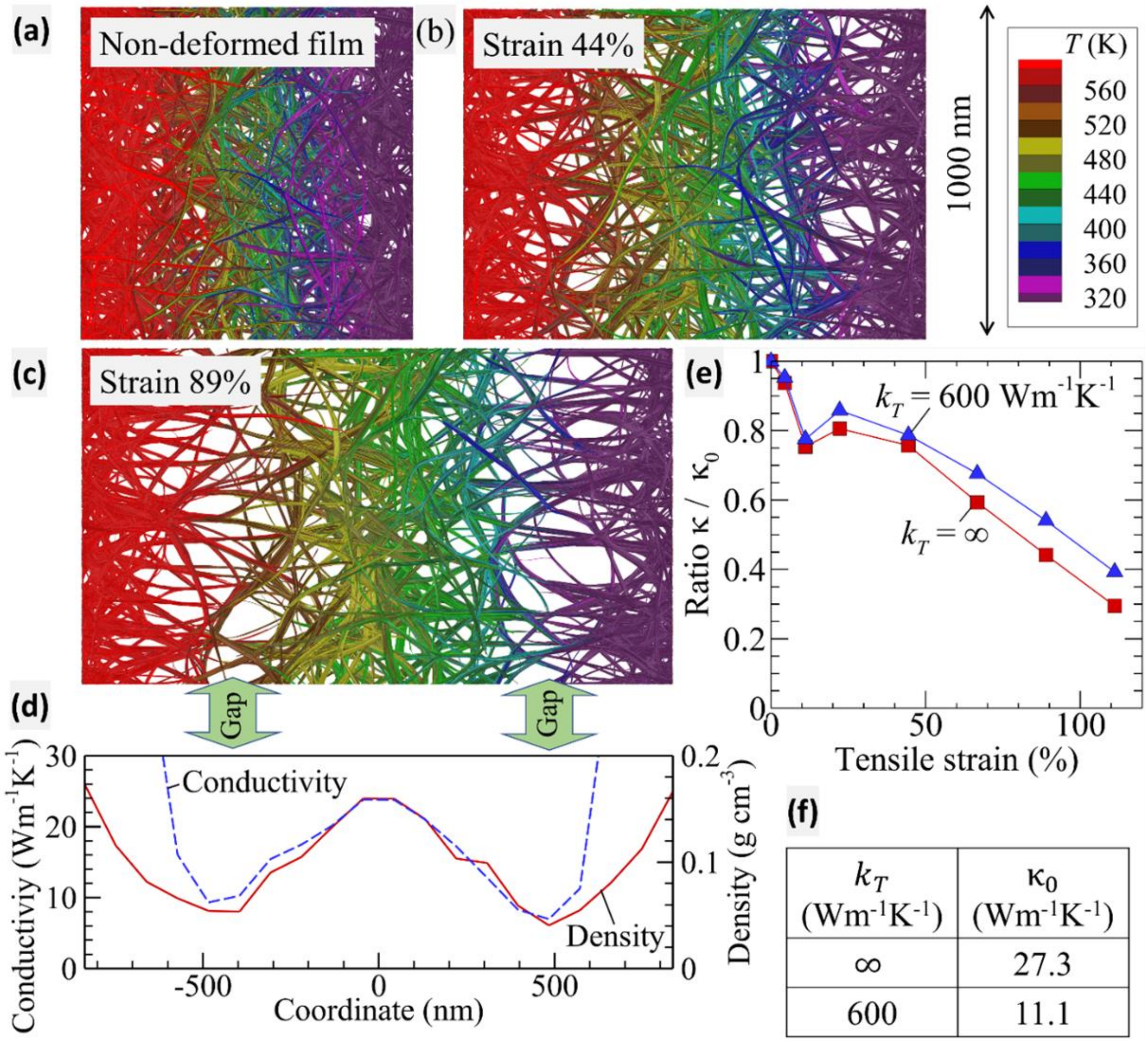


With the increase of DR, the electrical conductivity decreases, while the Seebeck coefficient increases a little bit.

❑ Thermal conductivity of heat-repaired CNT veil



❑ Mesoscopic simulations of thermal conductivity of stretched CNT veils



k_T (Wm^{-1}K^{-1})	κ_0 (Wm^{-1}K^{-1})
∞	27.3
600	11.1

4 Conclusion

1. PC/CNT/PC composites can form fragments via solid-state drawing, which can be repaired by thermal treatment.

2. A 3.5-fold reduction in thermal conductivity of CNT veils (from 46 to 13 W m^{-1} K^{-1}) has been achieved, combined with an increase in Seebeck coefficient of 10% and a decrease in electrical conductivity of 26%.

3. The maximum estimated ZT is 2.7 X 10^{-2} for heat-repaired PC/CNT/PC of DR =1.5.

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