One-Dimensional Metals

Some Pro's and Con's

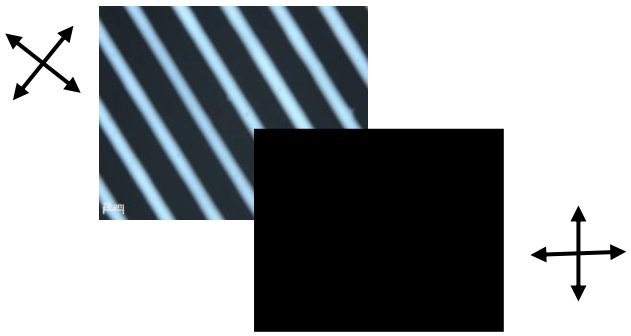
off-shore

anti-ballistics

transport

personal protection

Monolithic Materials



Time

Windows

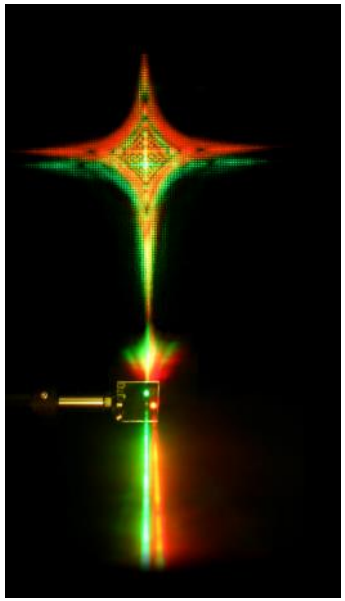
Actuators

Sensors

Renewable Energy

Liquid Crystal Displays

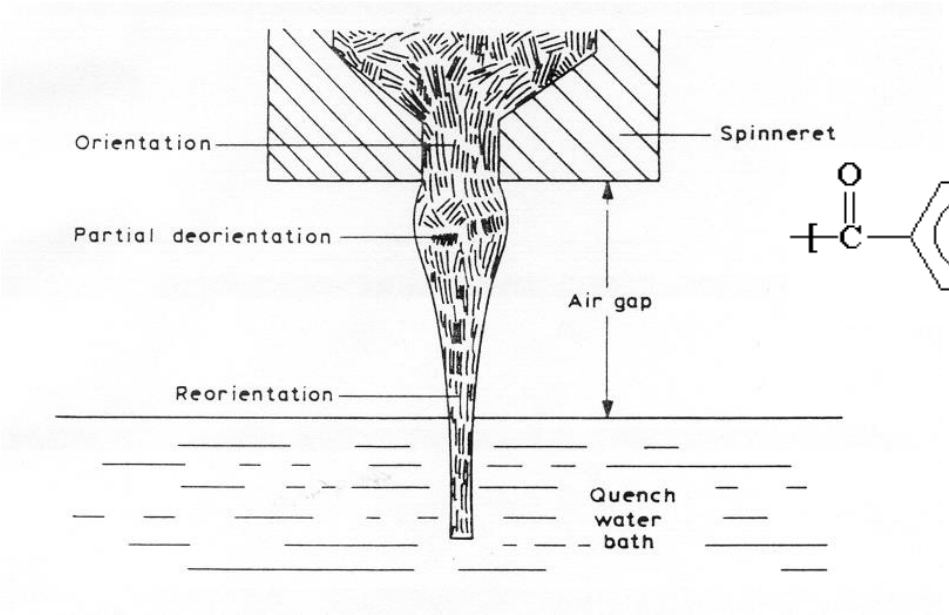
High Performance Fibres

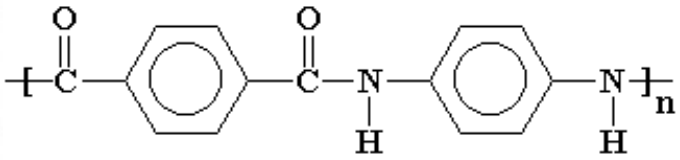


Nano- and micro-structuring

PPTA ; poly(p-phenylene terephthalamide)

Rigid macromolecules from liquid crystalline (lyotropic) solutions above a critical concentration





Tradenames : Kevlar (Dupont)
Twaron (Teijin)

Young's modulus : ~ 90 GPa
Tensile strength : ~ 3 GPa

Kwolek S.L. et al, Macromolecules, 10, 1390, (1977)

The drawing behaviour of semi-crystalline polymers is related to the deformation of a semi-crystalline network with entanglements acting as physical crosslinks

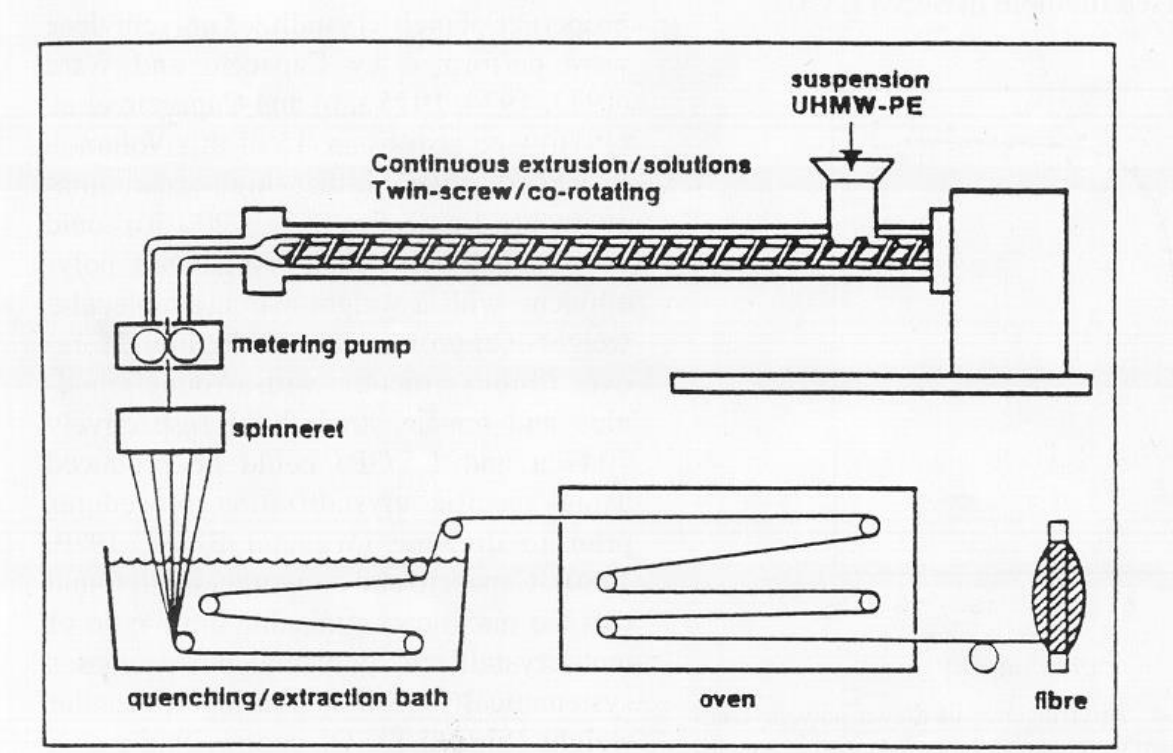


Figure 11-6. Schematic representation of the gel-spinning process (Lemstra et al., 1987 a).

$\lambda_{max} = \lambda_{max,melt}\, \phi^{0.5}$

Young's moduli > 150 GPa
Strength > 4 GPa

Smith and Lemstra, J. Polym. Sci., Phys. Ed., 877, 19, 1981

The Stiffness of Materials

Chain-extended polyethylene

Aromatic polyamides

Isotropic polyethylene

10^{3}

10^{2}

10^{1}

10^{0}

10^{-1}

10^{-2}

Young's modulus [GPa]

The Strength of Materials

Extended-chain polyethylene

Isotropic polymers

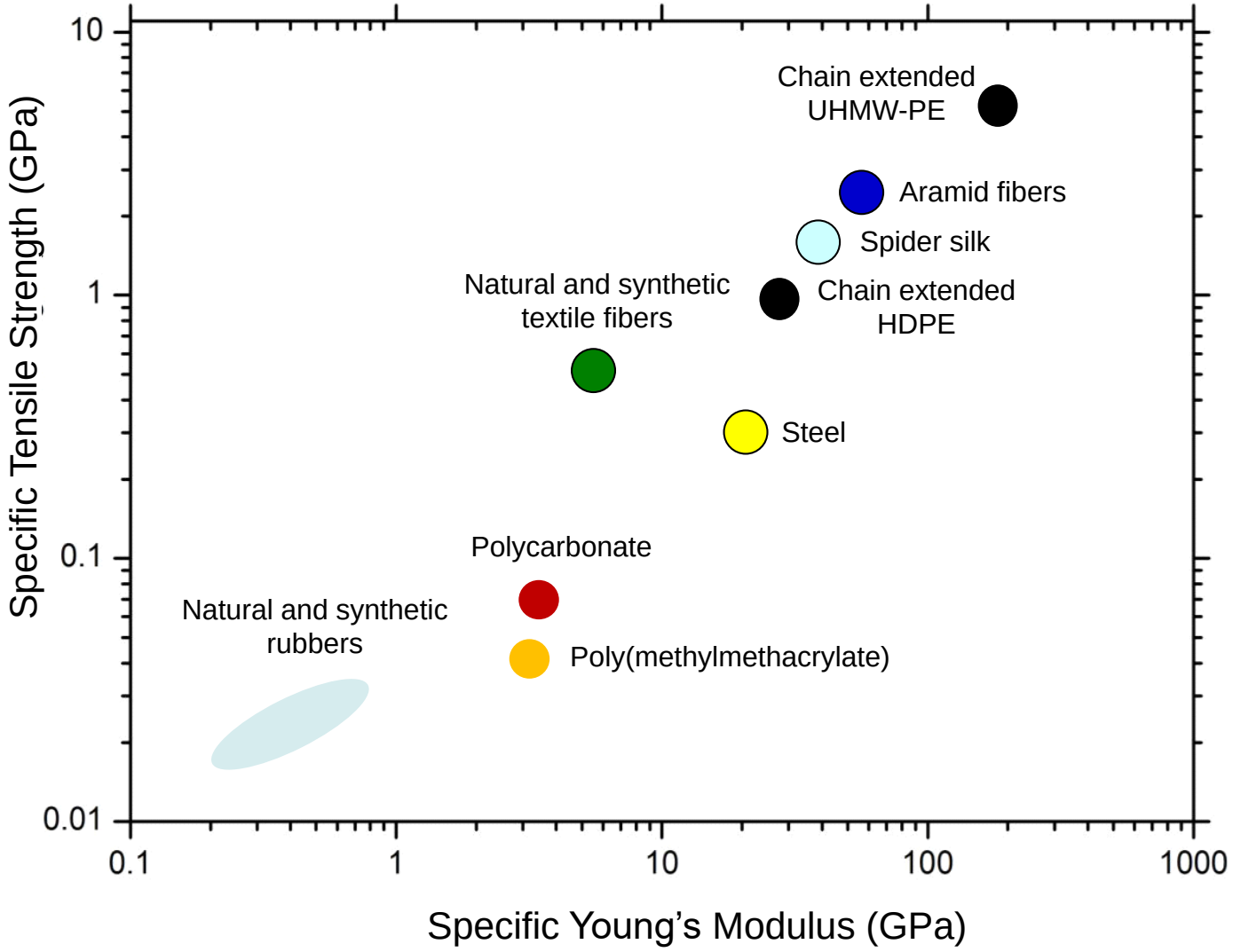
10

1

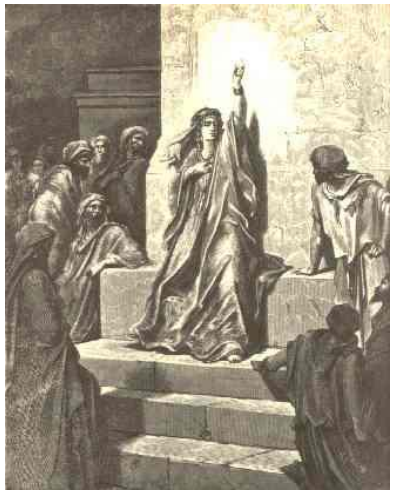
0.1

Tensile strength [GPa]

Specific modulus & strength of materials



The Deborah number



In theology (Judges 5:5)
On the time scale of God the mountains flow

In rheology
De = time scale of flow / time of observation
$De = (t_f) / t_{obs}$

At t_{obs} *= 100 years*

	Deborah number
water	$\sim 10^{-12}$
polymers	$\sim 10^{-9}$
chain-extended polymers	$\sim 10^{-3}$
glass (SiO_2)	$\sim 10^{-1}$
steel	$\sim 10^{0}$
diamond	$\sim 10^{2}$

The question is not whether it will flow
The question is when it will flow

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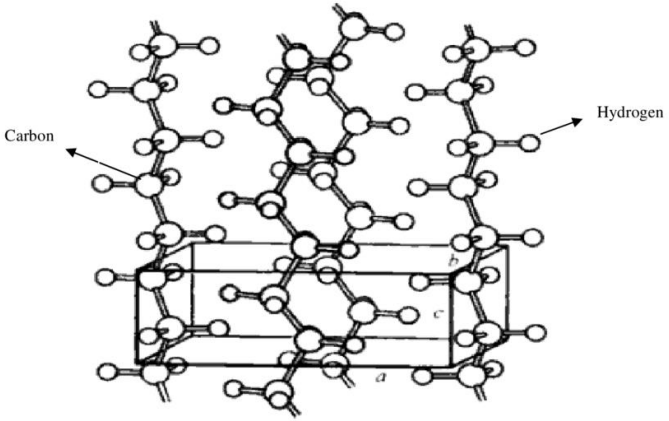
The orthorhombic crystalline unit cell

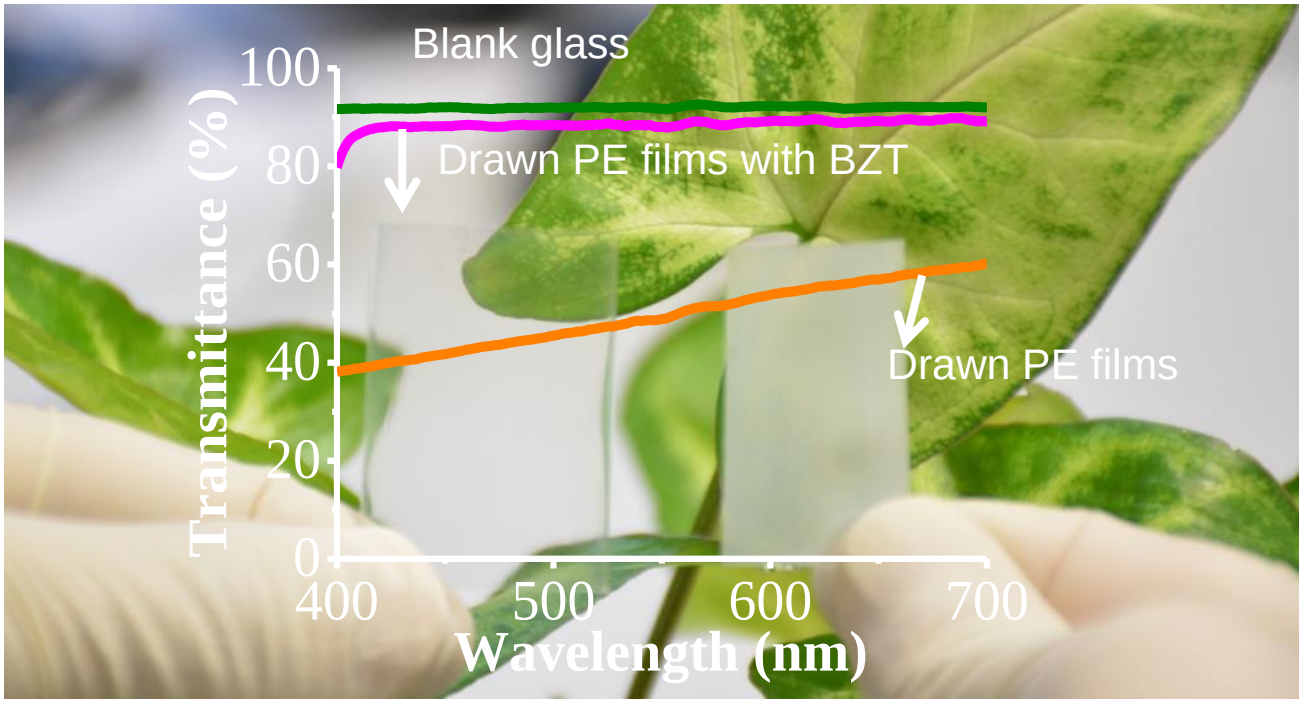


The (theoretical) stiffness matrix

$$C_{pq} = \begin{vmatrix} 7.99 & 3.28 & 1.13 & 0 & 0 & 0 \\ 3.28 & 9.92 & 2.14 & 0 & 0 & 0 \\ 1.13 & 2.14 & \mathbf{316} & 0 & 0 & 0 \\ 0 & 0 & 0 & 3.19 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.62 & 0 \\ 0 & 0 & 0 & 0 & 0 & 3.62 \end{vmatrix} \text{ GPa}$$

1-dimensional high modulus (& strength)

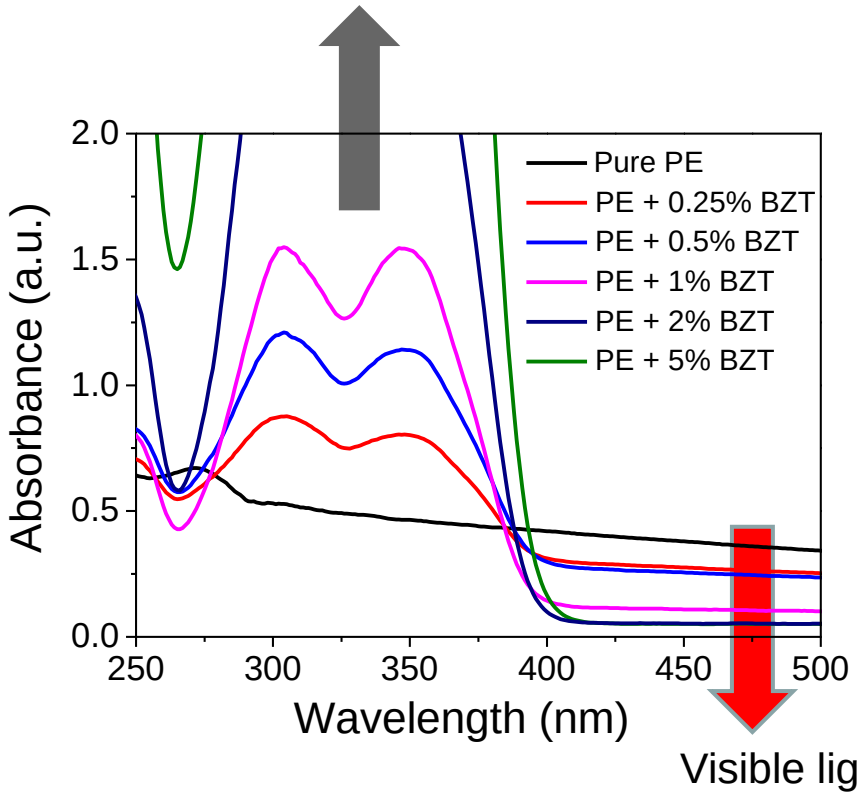
Why Start Again ?



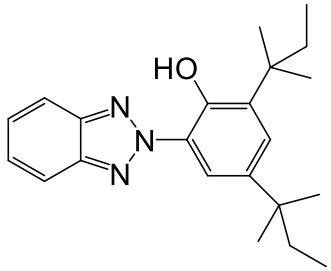
Light scattering in drawn HDPE:

- Surface scattering, fibrillar surface structure (coating, adhesive)
- Bulk scattering in tapes, films (additives)

Ultra-violet ”black”, drawn HDPE



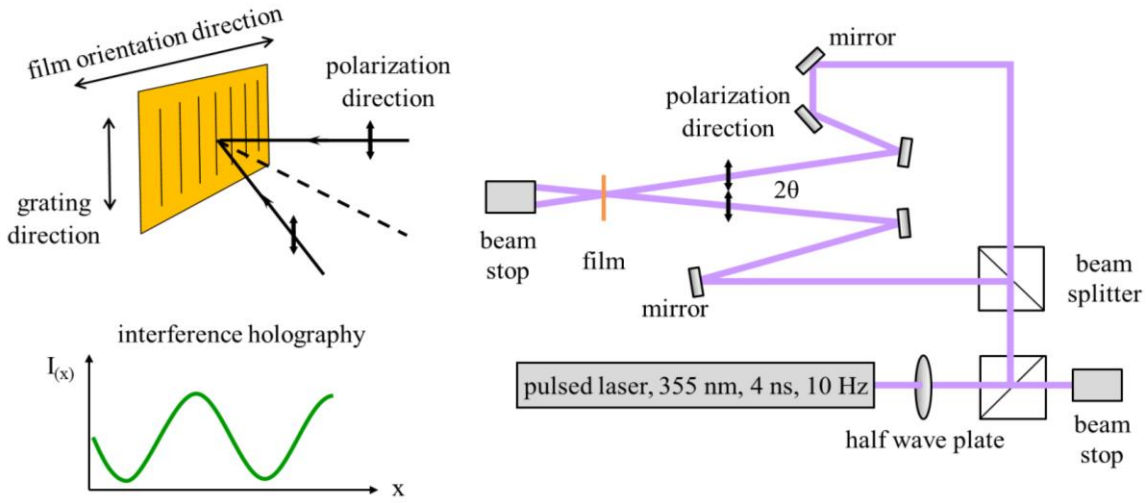
Visible light region

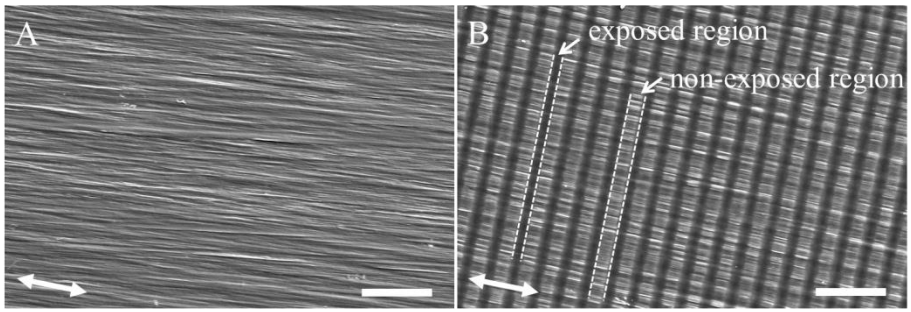


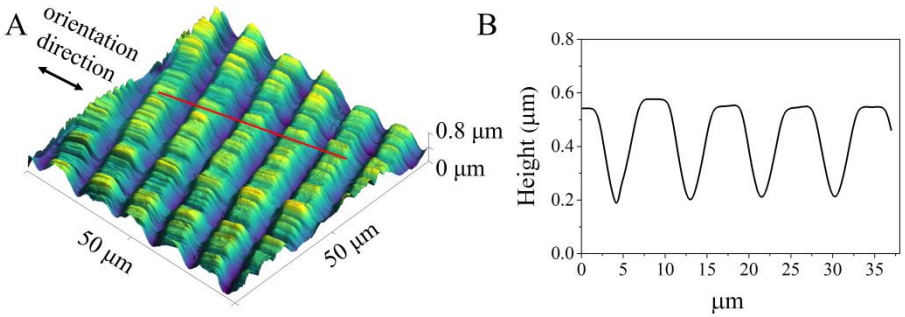
Benzotriazoles (BZT)

Filling of defect-structures such as nano & micro-voids

Interference holography (recording)

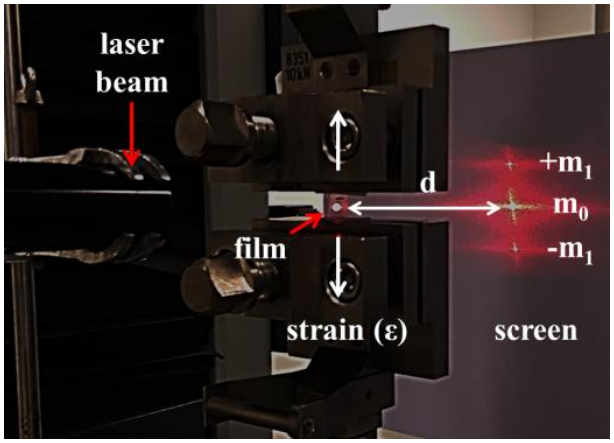


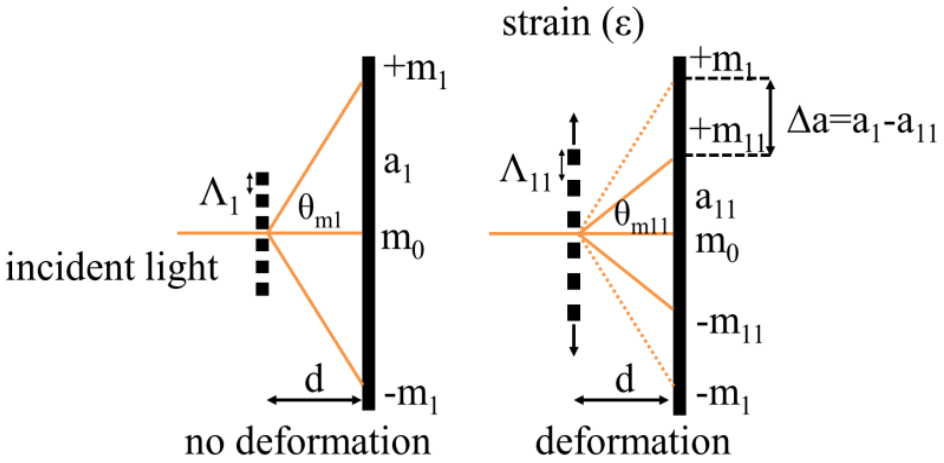


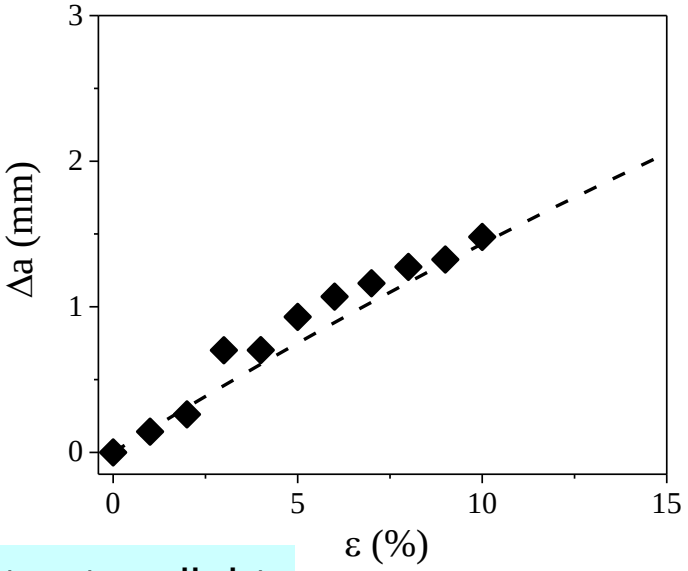


Local melting & relaxation

Visible light diffraction (reading)

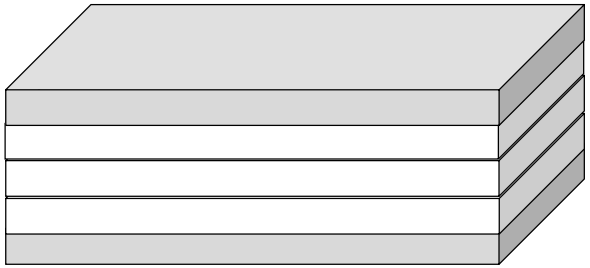




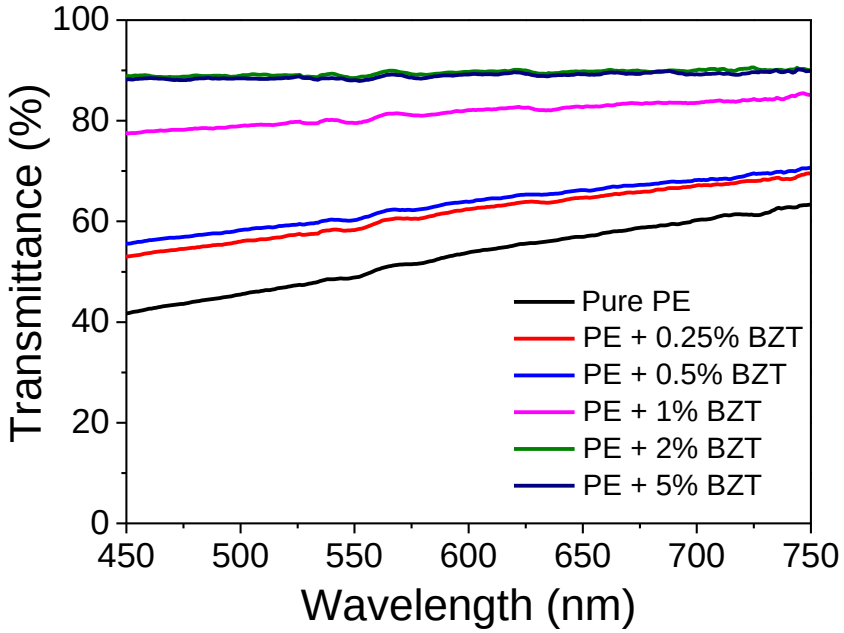


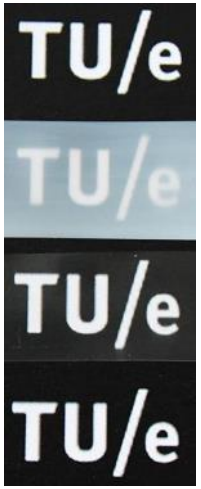
Structuring with light to structure light

polymer + additive → compounding → extrusion → ultra-drawing → lamination



glass
coating (adhesive)
ultra-drawn HDPE
coating (adhesive)
glass



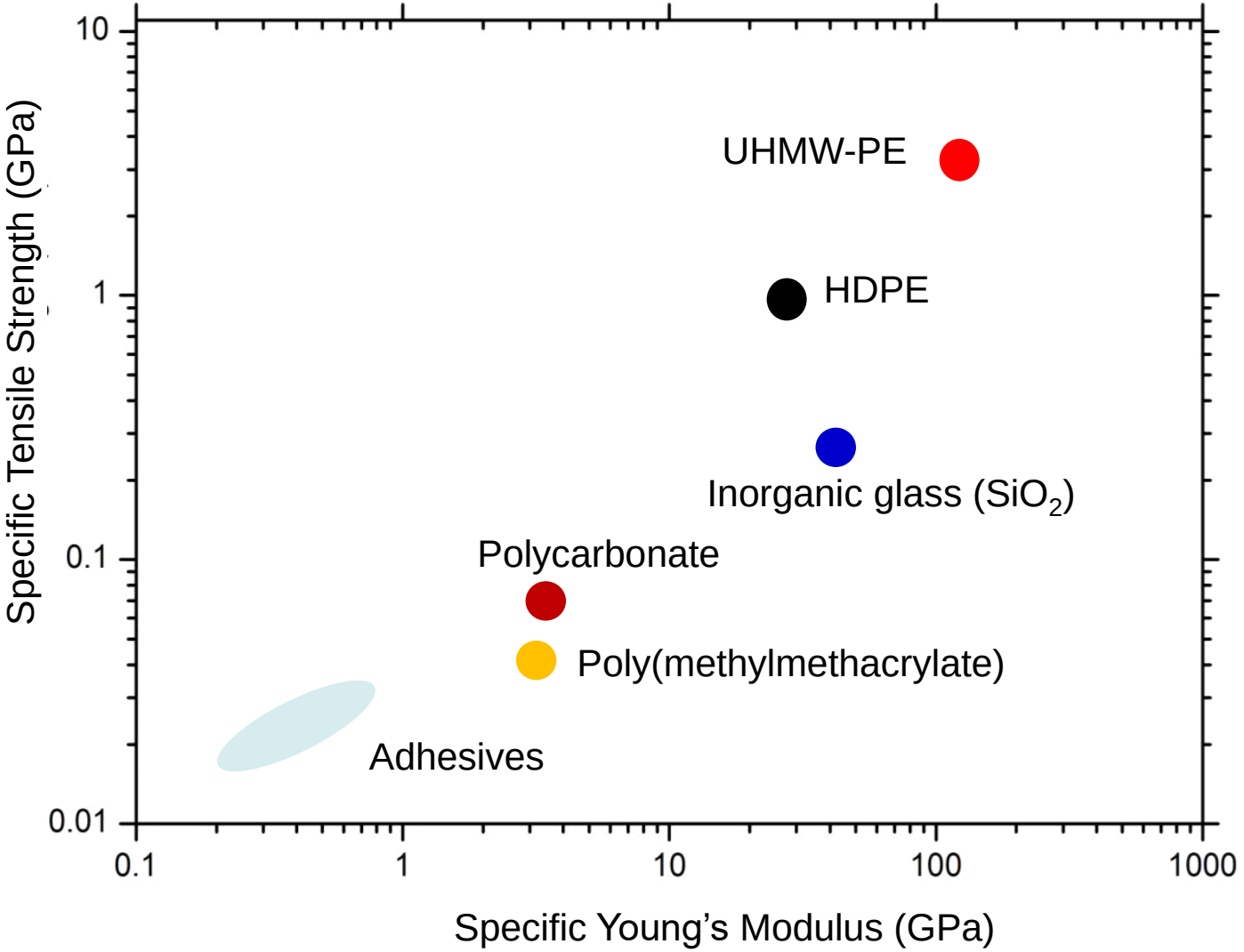


⇦ nothing

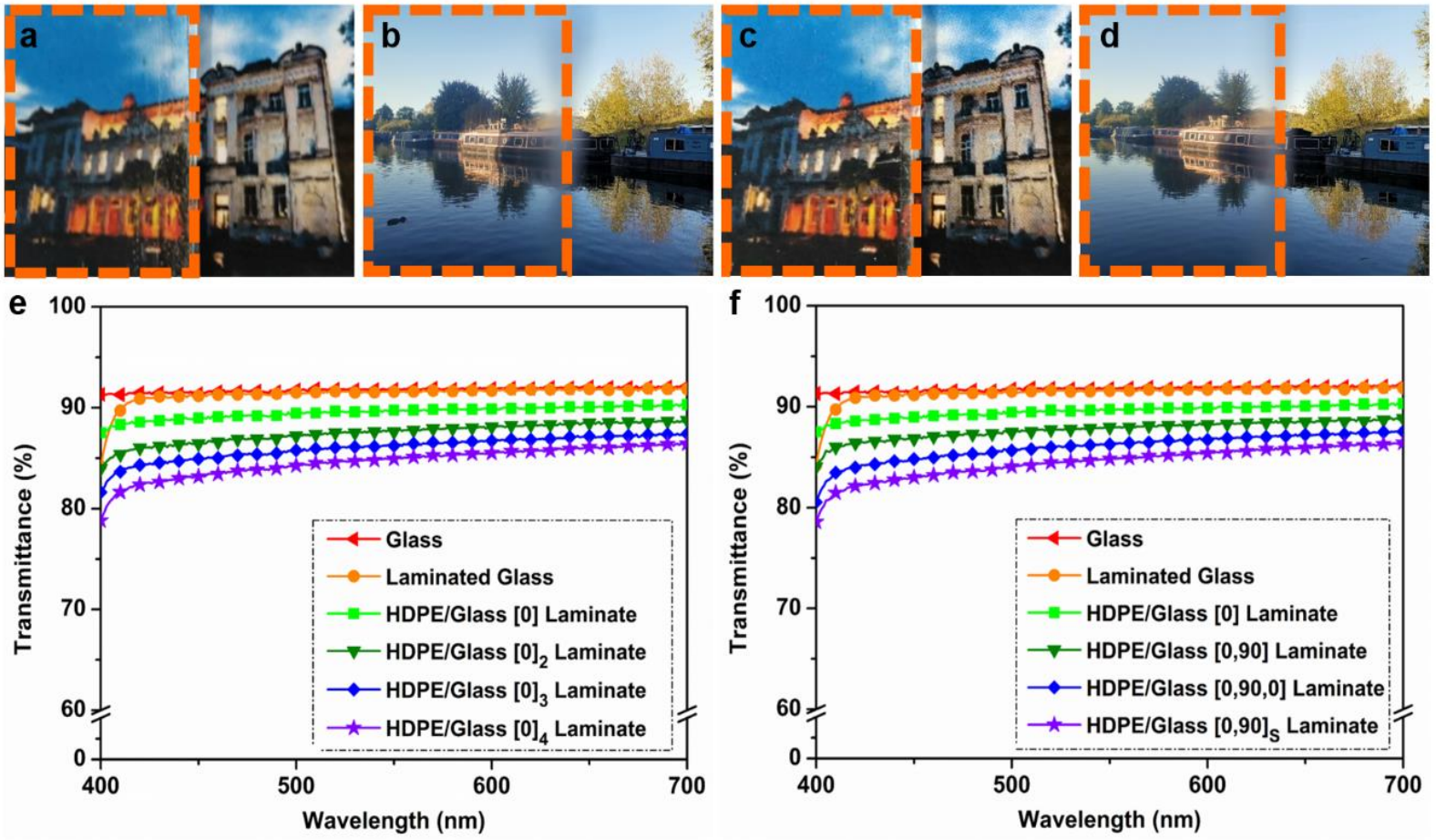
⇦ ultra-drawn PE

⇦ 2 % wt/wt BZT

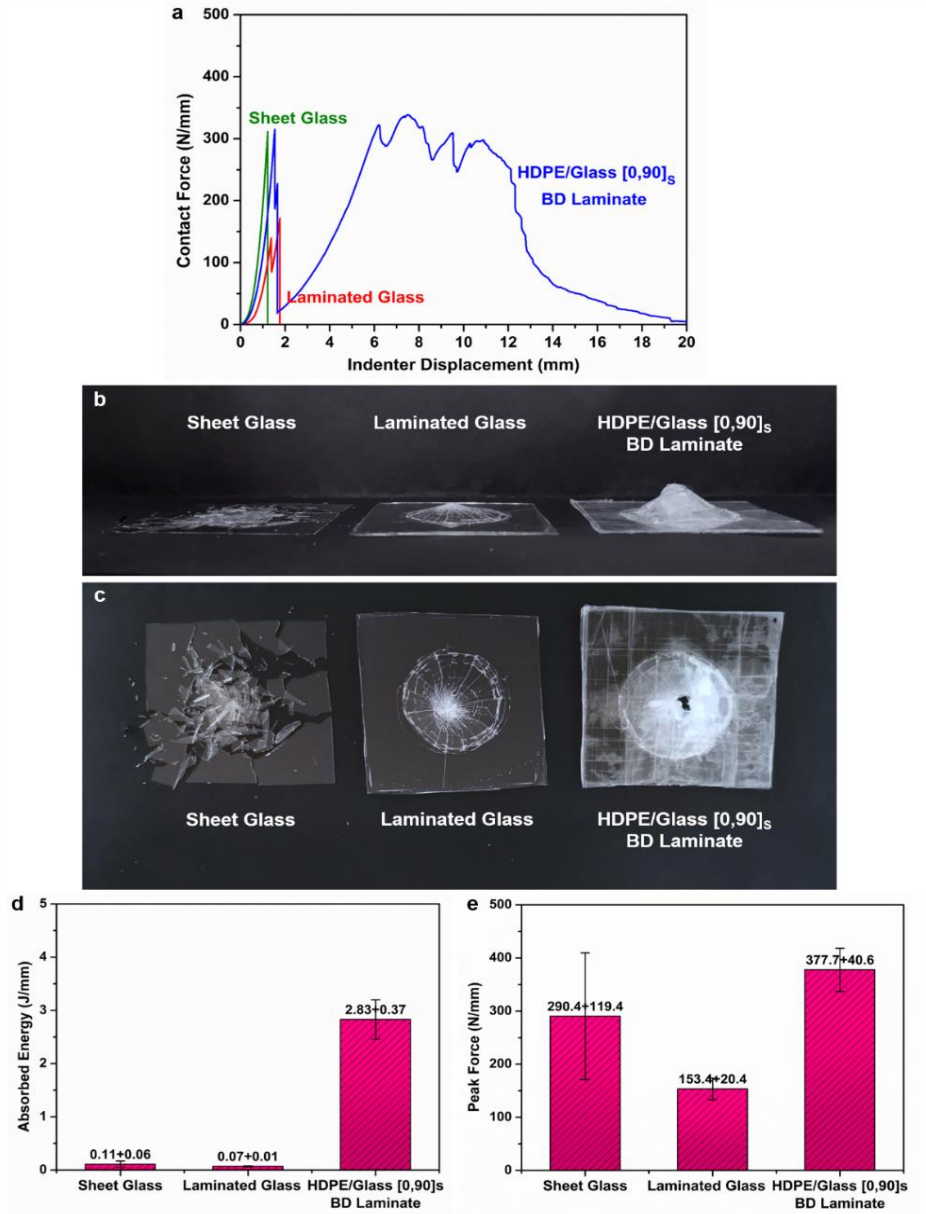
⇦ glass


Specific Tensile Strength (GPa)
10
1
0.1
0.01
0.1
1
10
100
1000
Specific Young's Modulus (GPa)
UHMW-PE
HDPE
Inorganic glass (SiO_2)
Polycarbonate
Poly(methylmethacrylate)
Adhesives

In plane, quasi-isotropic mechanical and optical properties

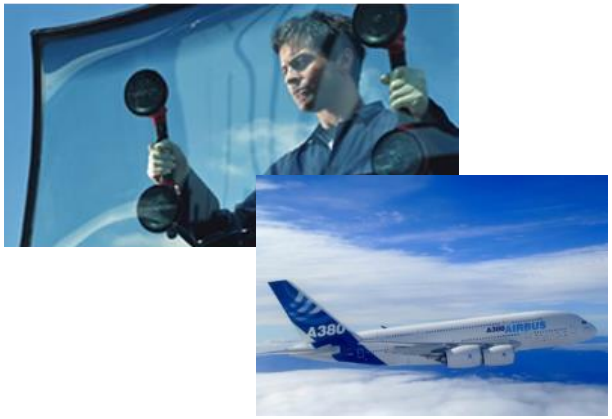


Cross-ply (0/90) laminates



Light Weight & High-Impact Glass

Transport
Automotive, trains, planes



Life Protection

Safety, Security Glass

Shops, gas stations, banks, embassies,

Displays
(Gorilla glass)

Chain-Extended Polymers
Soft vs Hard Robotics

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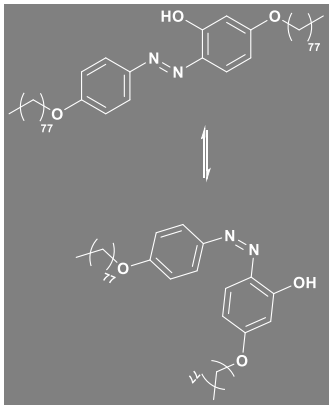
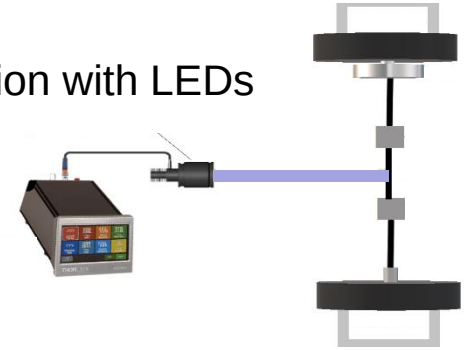
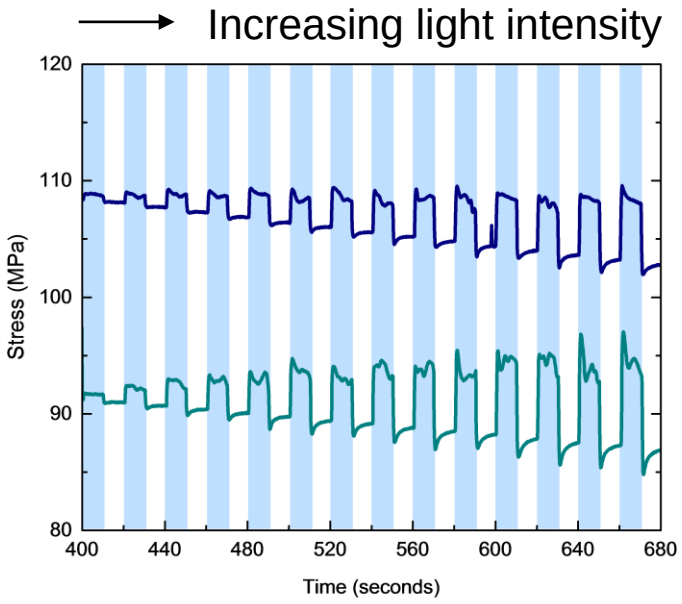
Light responsive Azo compounds with aliphatic tails and/or BZT



Illumination with LEDs



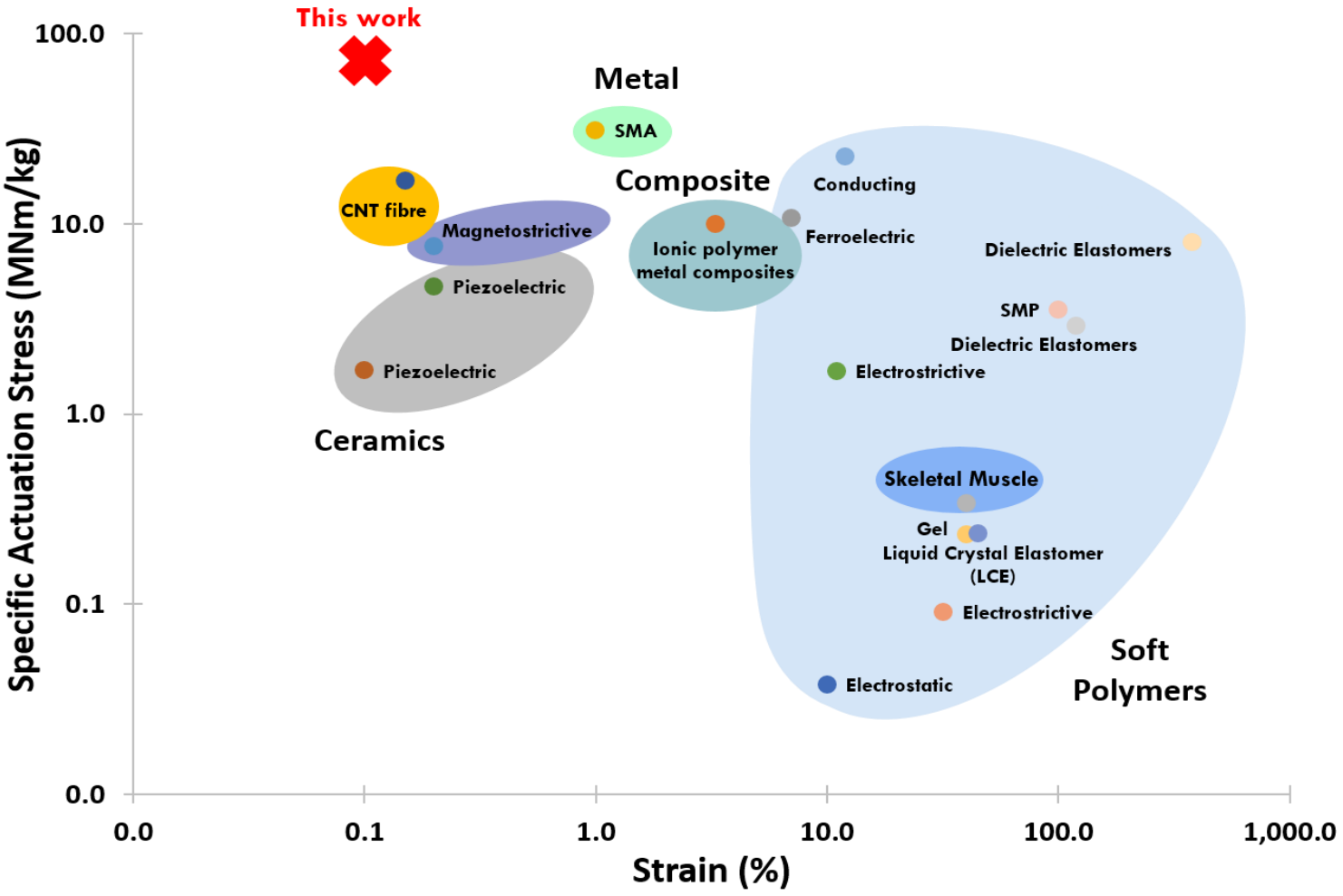


Switching speed < 1 sec

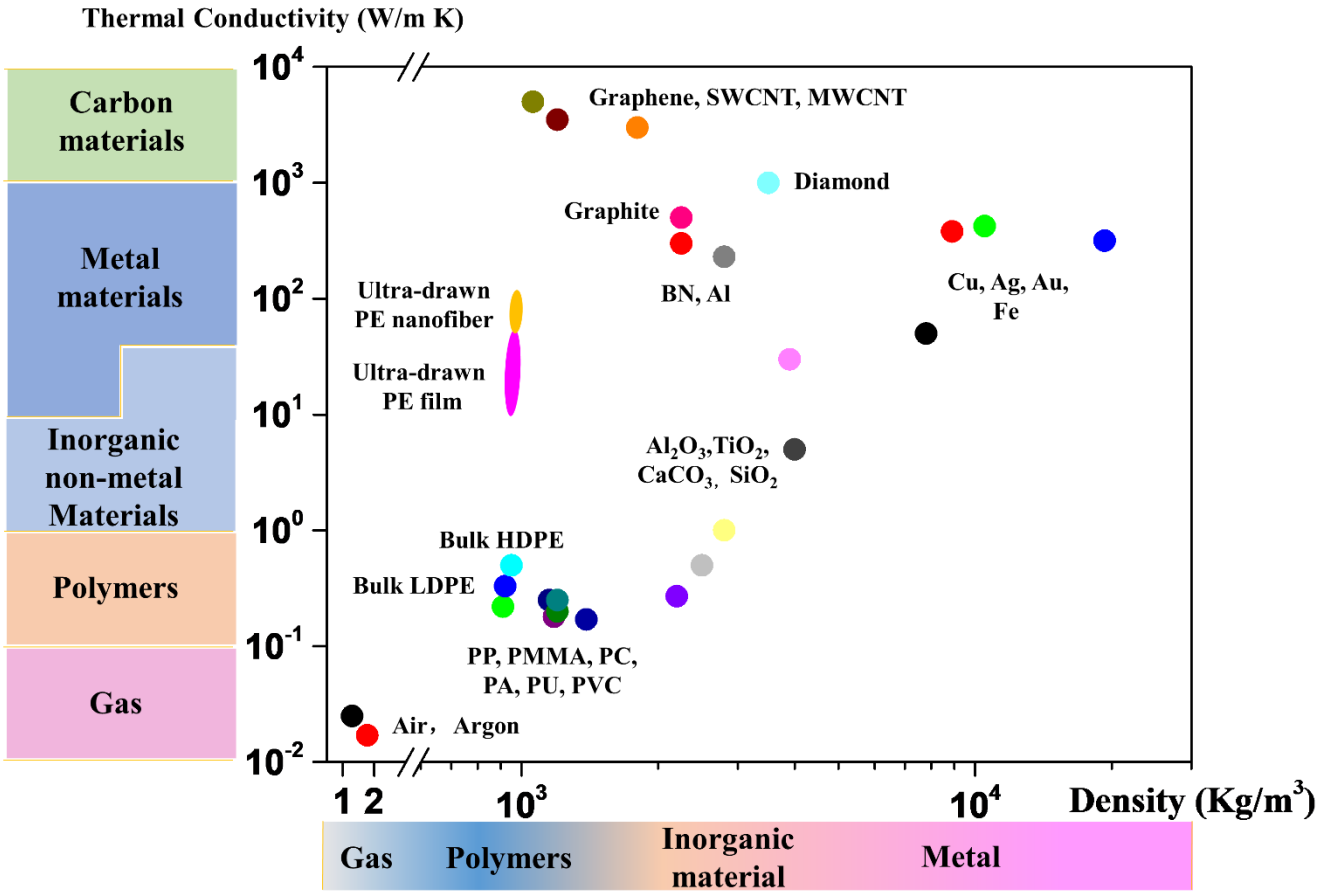
Mechanism :
- High thermal conductivity
- Large and negative thermal expansion coefficient
- High Young's modulus

Properties
- High actuation stress (>200 x muscle)
- Very low strain (< 1 %)
- Moderate work

Chain-Extended Polymers
Soft vs Hard Robotics



Thermal conductivity



Chain-Extended Polymers
Transparent Thermal Conductors

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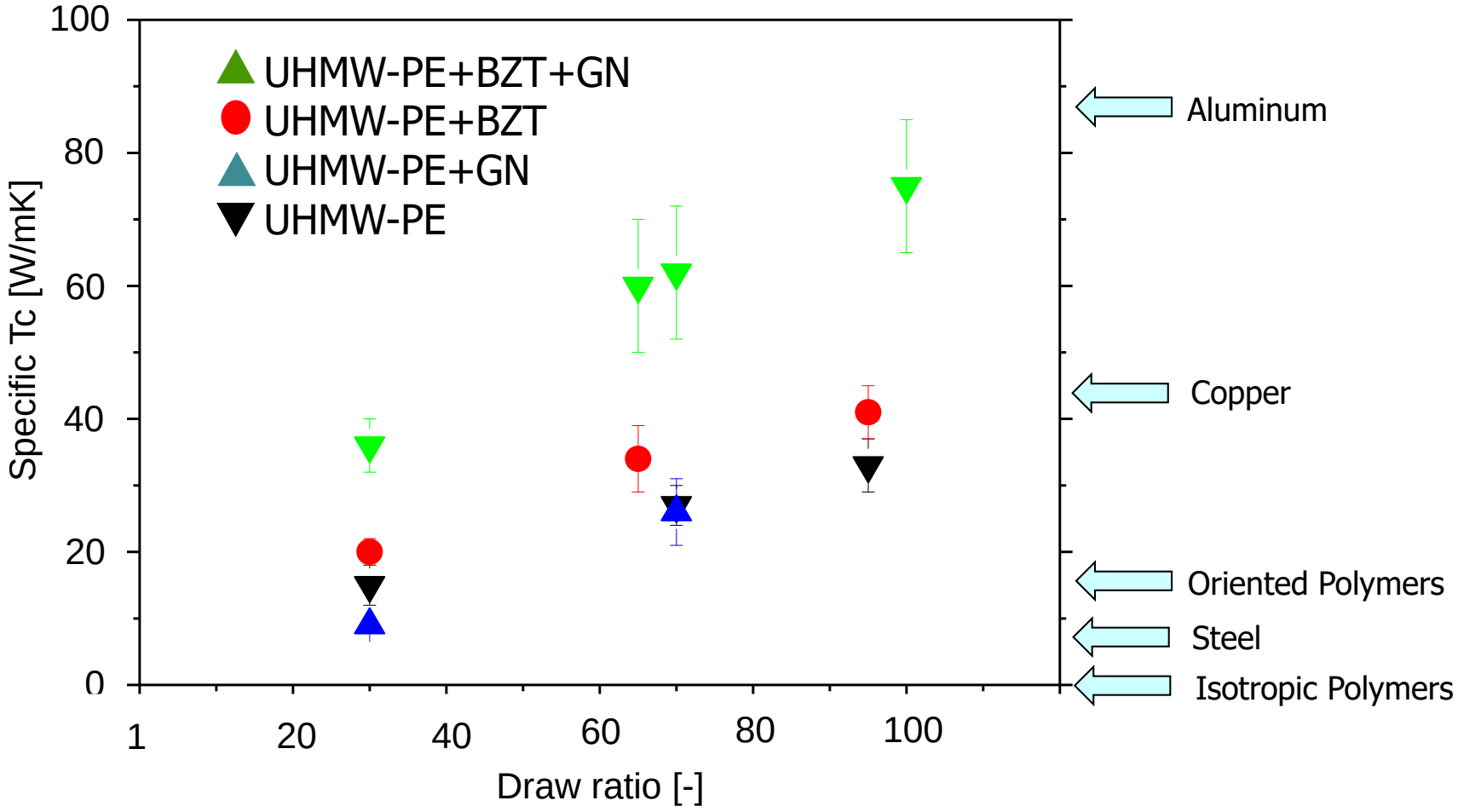

Keep it Cool

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Build Environment

Transport

Greenhouses

Solar Energy

Electronics