Elasto-Viscoplastic Damage in Polyethylene Under Chemical Environment

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HDPE and UHMWPE

High density polyethylene

High-density polyethylene (HDPE) is a thermoplastic polymer commonly used in applications from plastic bottles to transport pipelines.

Ultra High Molecular Weight Polyethylene

Ultra high molecular weight polyethylene (UHMWPE) is a thermoplastic polymer with a highly crystalline structure.

Both are susceptible to failure due to crack growth which can be aggravated by chemical environment and temperature.

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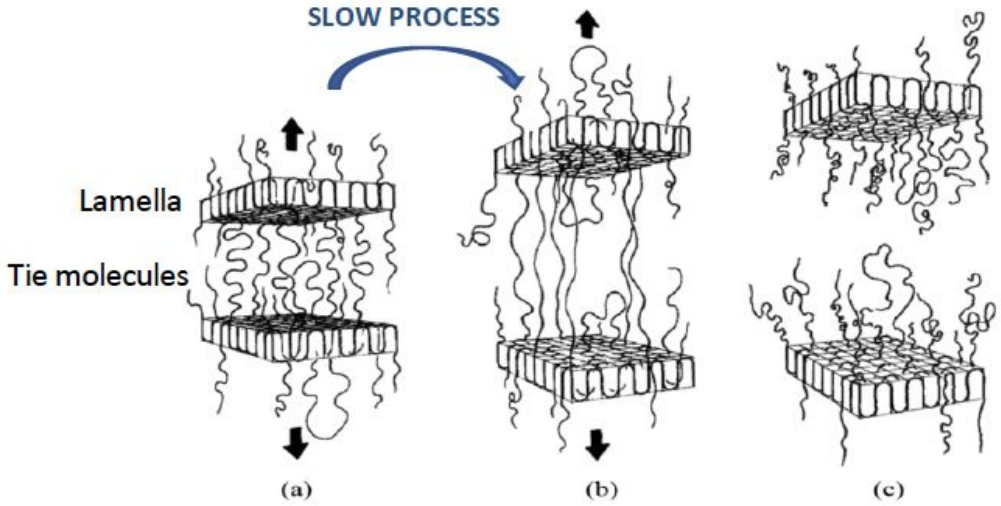
A. Lustiger and R. Markham, Polymer (Guildf)., 1983
M. Schilling, U. Niebergall, and M. Böhning, Polym. Test., 2017
N. Patil, J. Njuguna, and B. Kandasubramanian, Eur. Poly., 2020

Failure mechanisms in PE



semicrystalline polymer = crystalline + amorphous

In the figure, a, b, c [1] present the process of disentanglement of polyethylene polymer lamellae due to creep.

Failure process:

a) Lamellae start to pull away due to creep in amorphous phase
b) Tie molecules are stretched tight and untangle
c) Clean break of lamellae

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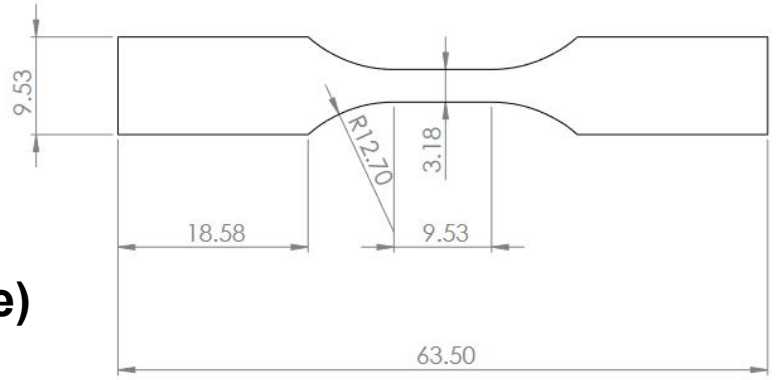
1.Lustiger and Markham (1983) *Polymer (Guildf).*

Materials and Methods

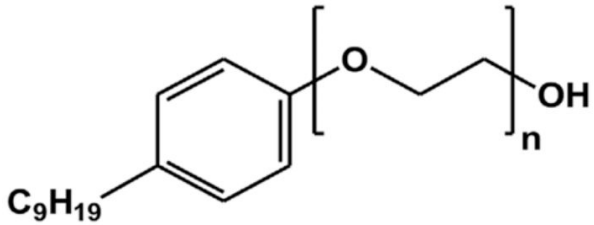
Sample Types

- Notched/Cracked Samples
- Unnotched Samples

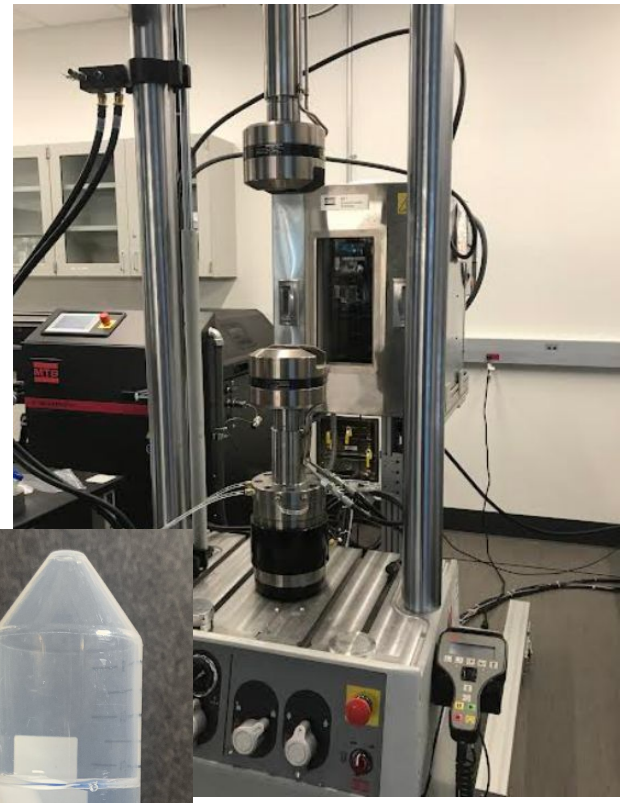


Chemical Treatments (14 day exposure)

- Phosphate Buffered Saline (PBS)
- 10% Igepal CO-630



ASTM D638 Type V



Temperature Conditions

- 22 ºC (Room Temp)
- 37 ºC (Body Temp)
- 50 ºC (Industrial Temp)

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R. Qian, X. Lu and N. Brown, Polymer, 1993
A. Lustiger and R. Markham, Polymer (Guildf)., 1983
DataPointLabs, 2014

Strain-rate dependency in unnotched samples

HDPE

UHMWPE

in-air, 22C

- At very slow strain rates, significantly smaller amounts of stress will lead to onset of plastic deformation.
- HDPE experiences strain softening; UHMWPE experiences strain hardening

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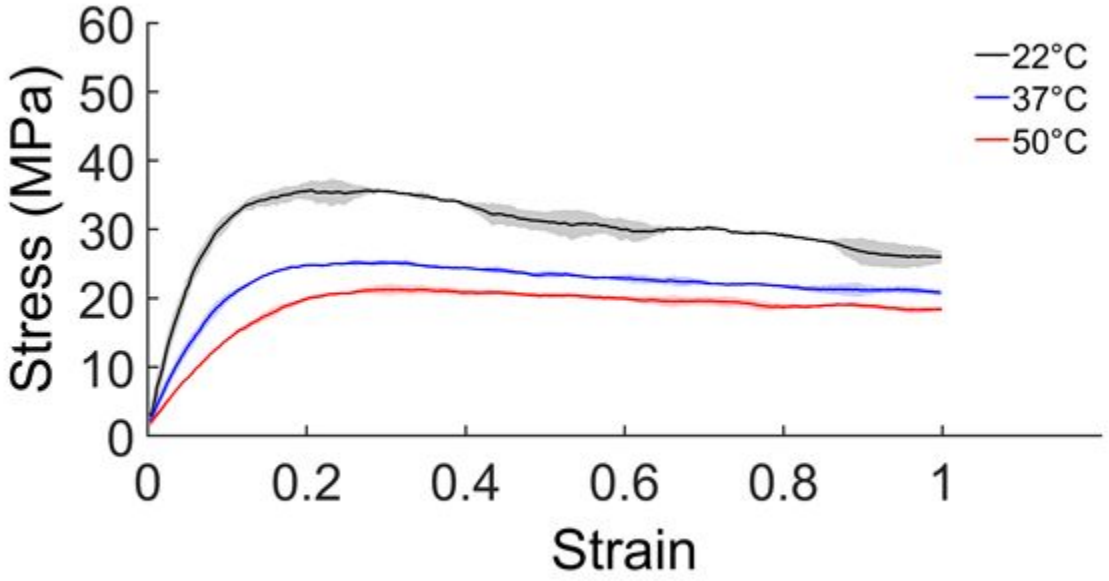
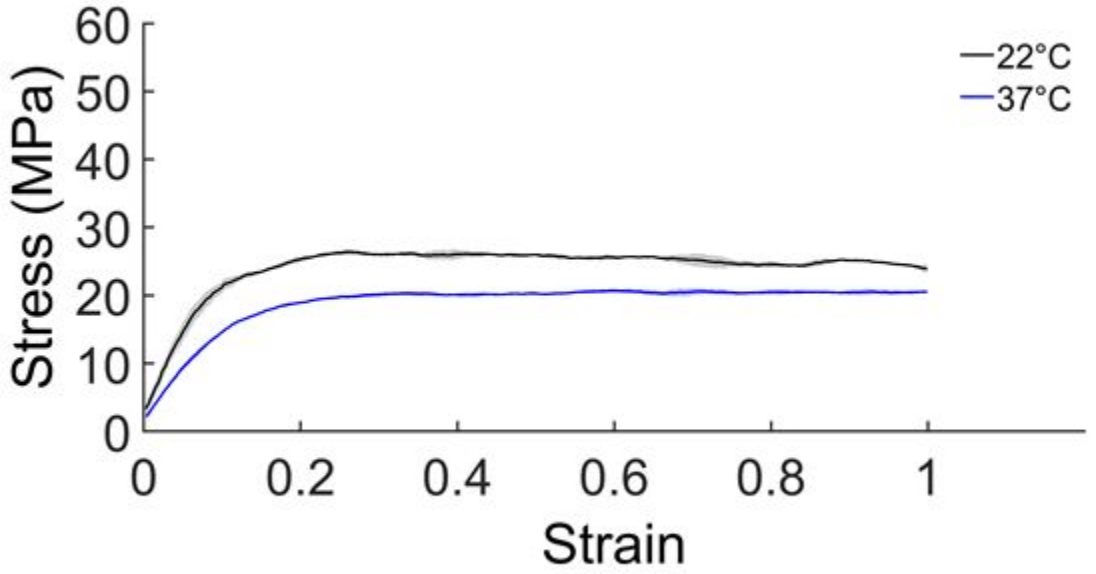
Effect of temperature in unnotched samples

HDPE



UHMWPE



0.0003 s^{-1}, in-air

As the temperature increases, the maximum tensile stress decreases and the polymer becomes more ductile.

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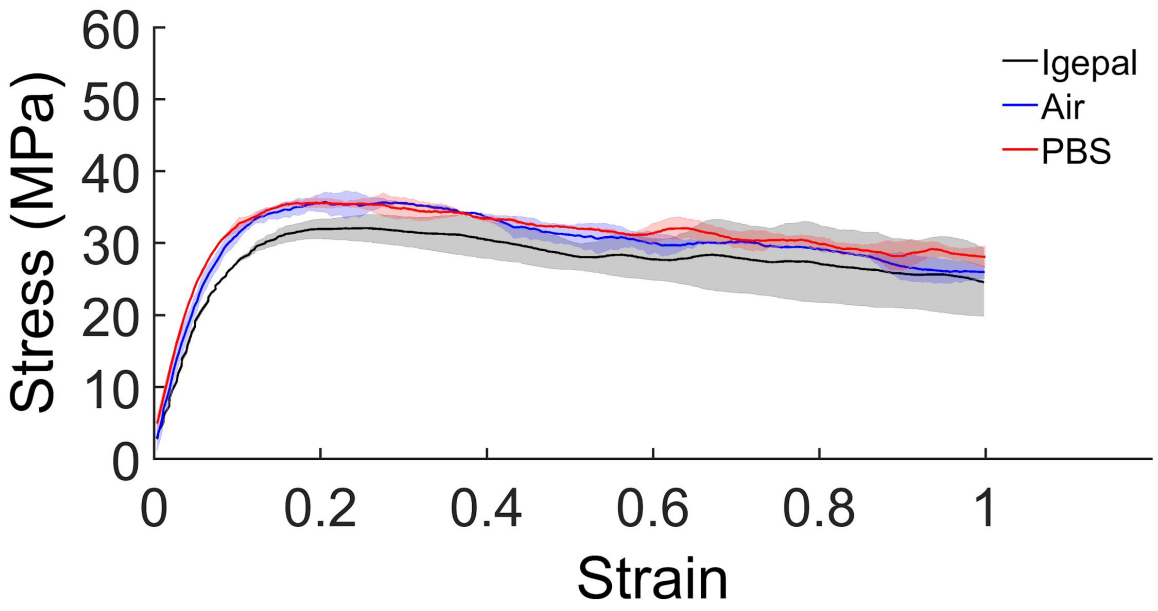
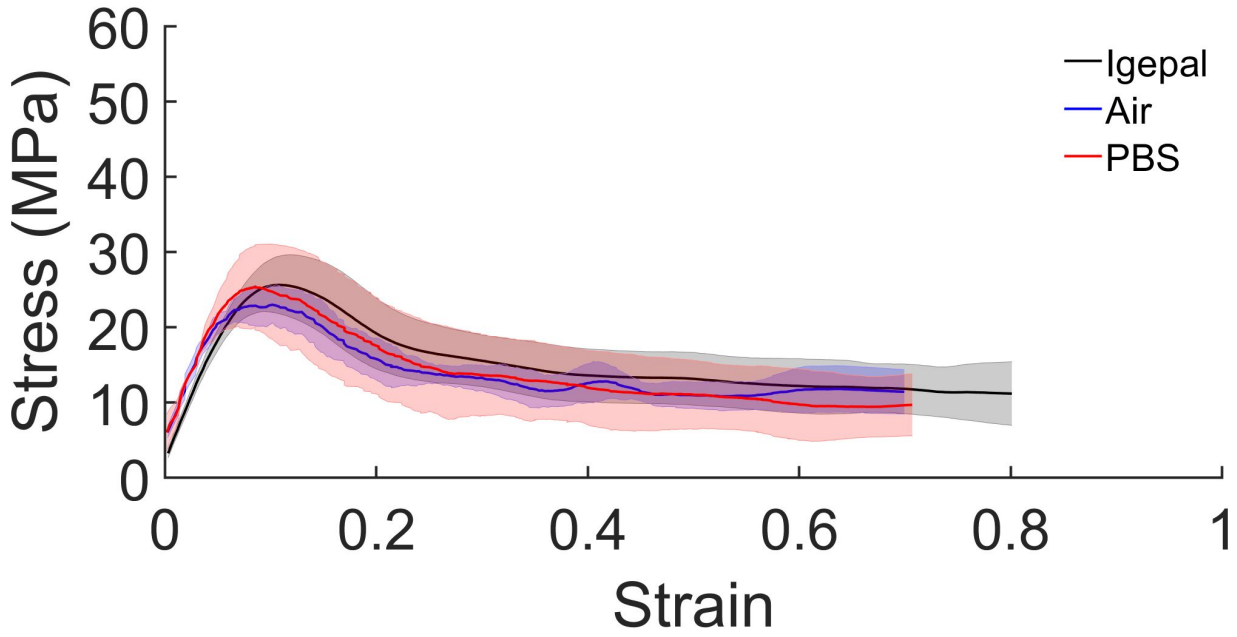
Effect of chemical environment on HDPE

Unnotched



Notched



$0.0003\ s^{-1}$, 22C

Under current conditions, there is no observed effect of Igepal or PBS on the strain and time to failure observed in HDPE.

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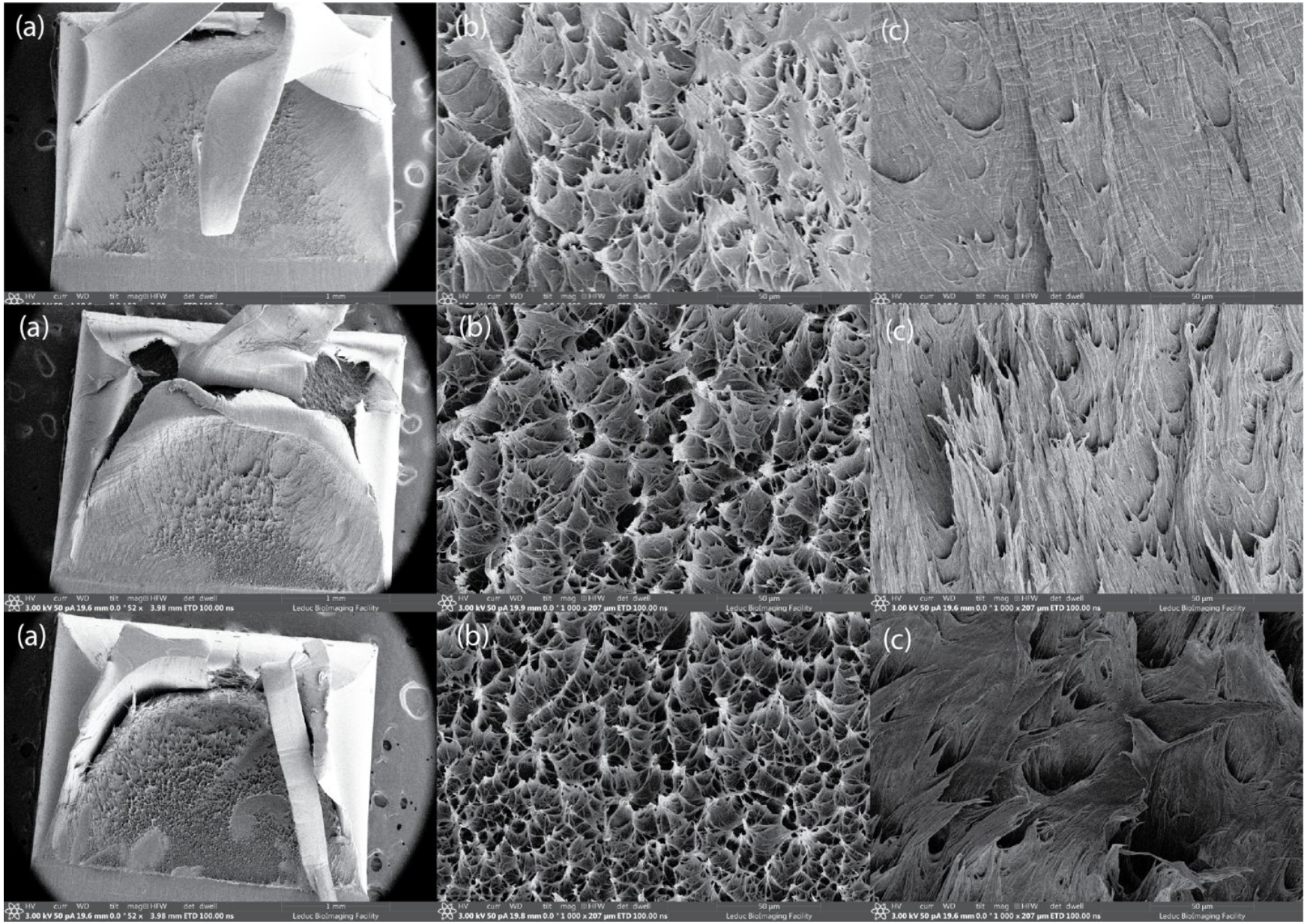
Scanning Electron Microscopy (Fracture Surfaces)

22 ºC

37 ºC

50 ºC



HDPE

0.0003 s^{-1}

in-air

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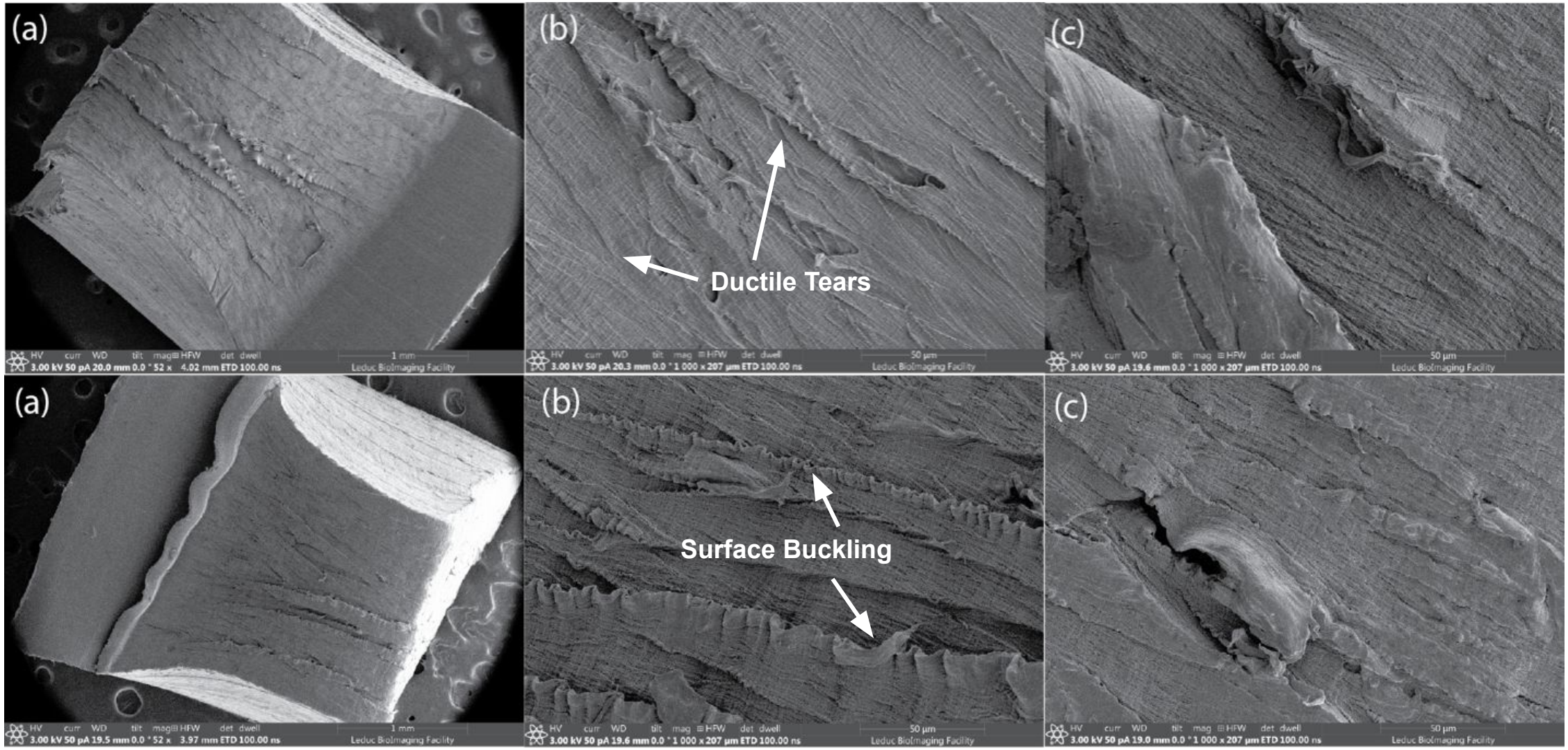
Scanning Electron Microscopy (Fracture Surfaces)

22 ºC

37 ºC

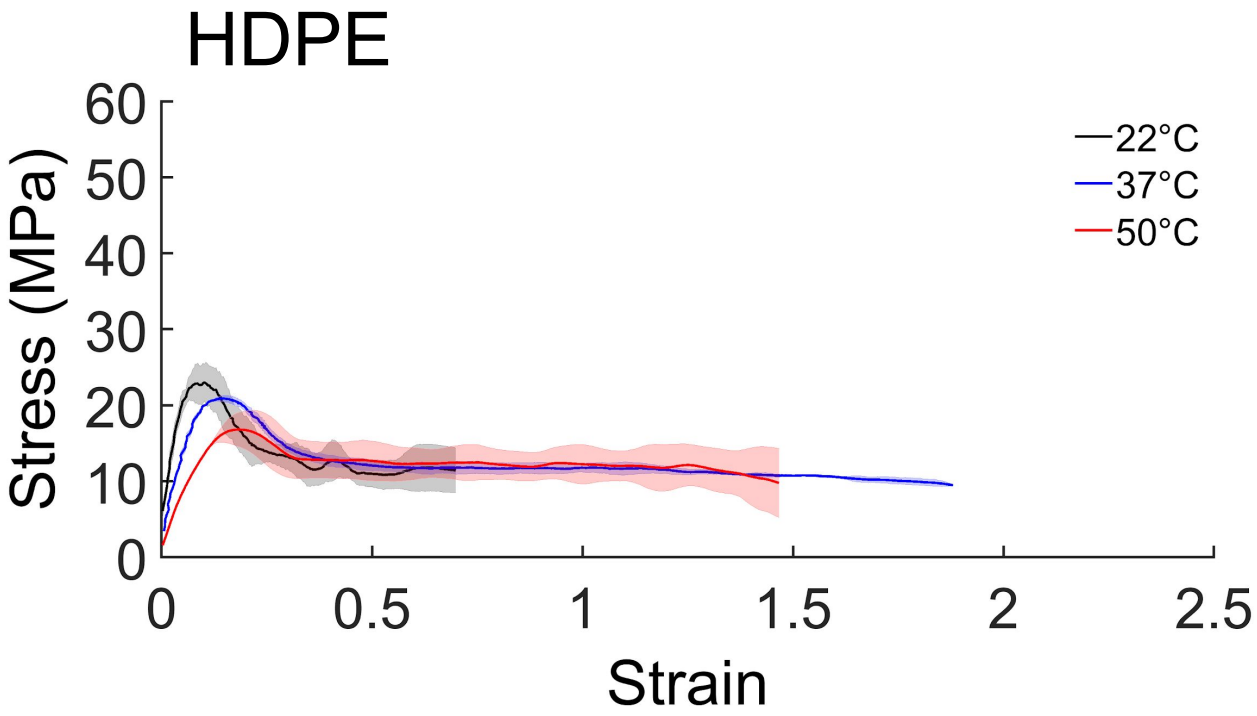


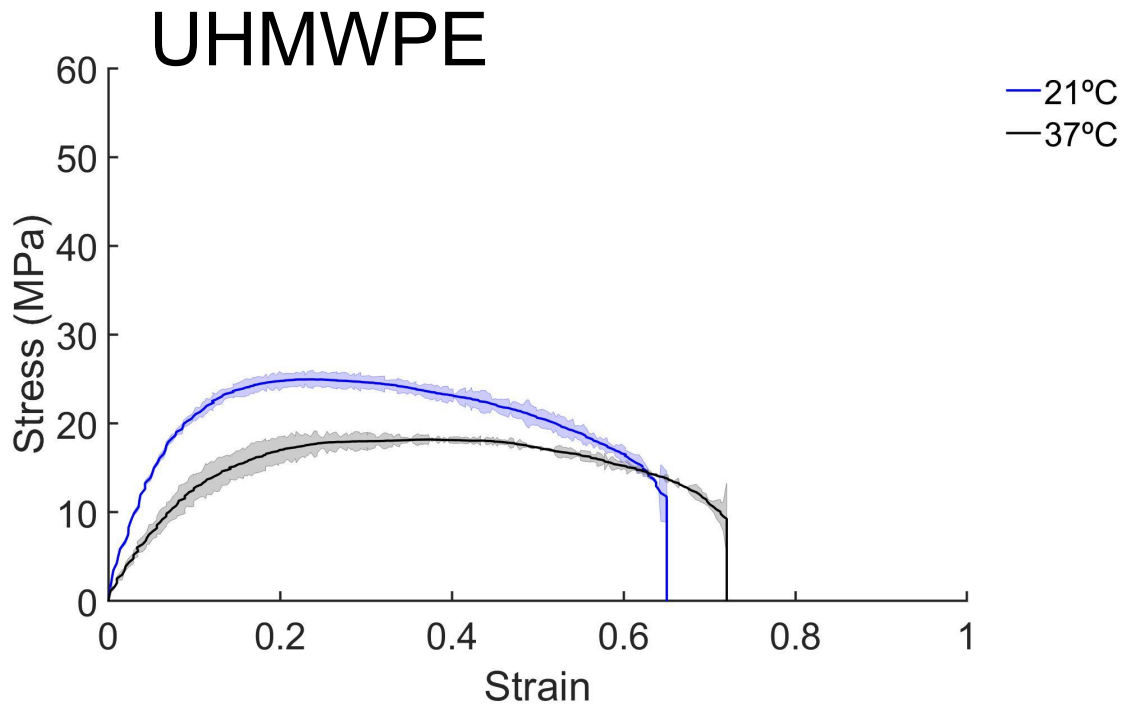
UHMWPE, 0.0003 s^{-1}, in-air

Thank you!

Questions?

Effect of temperature in notched samples





0.0003 s^{-1}, in-air

As the temperature increases, the maximum tensile stress decreases while the time to failure increases.

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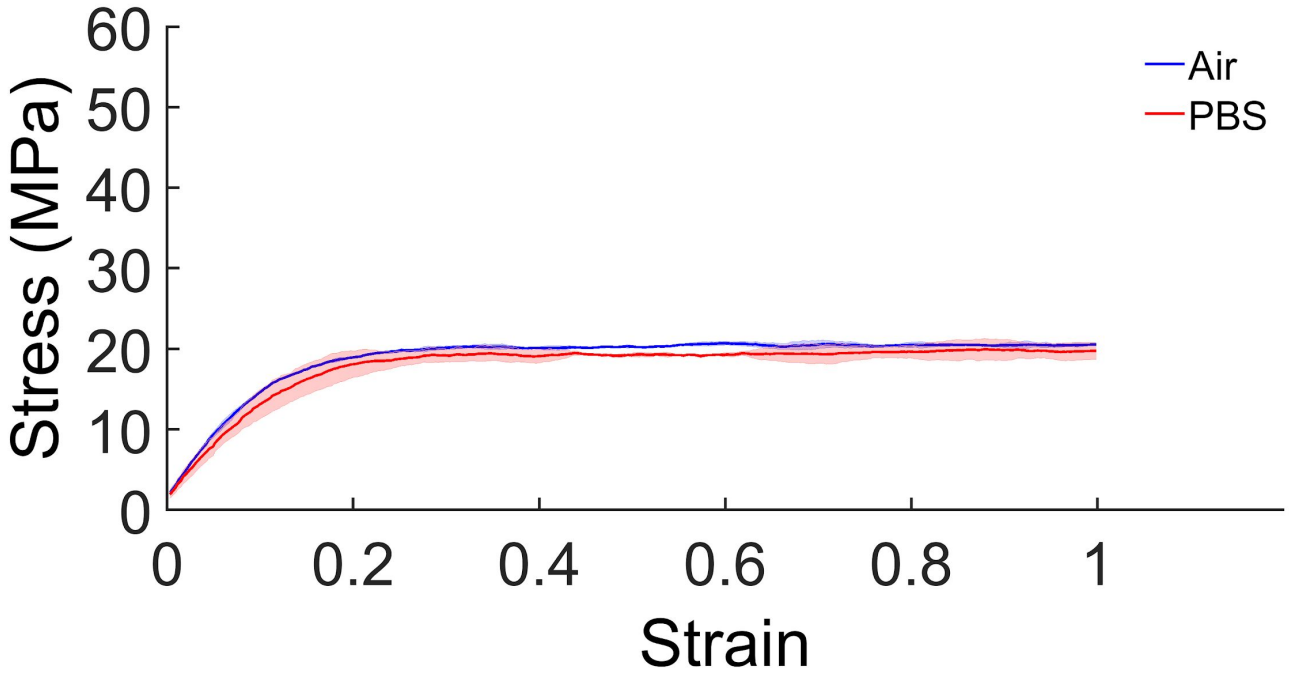
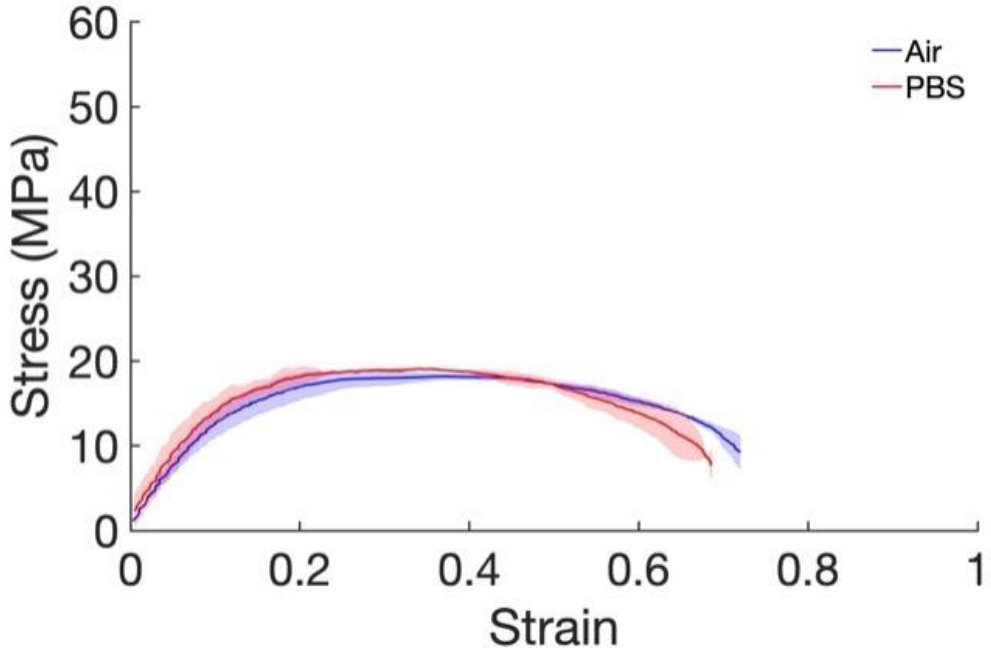
Effect of chemical environment on UHMWPE

Unnotched



Notched



0.0003 s^{-1}, 37C

Under current conditions, there is no observed effect of PBS on the strain and time to failure observed in UHMWPE.

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