University of BRISTOL
Bristol Composites Institute (ACCIS)

Plasma surface modification of UHMWPE and its effects on adhesion and wettability

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ACCIS
ADVANCED COMPOSITES COLLABORATION FOR INNOVATION & SCIENCE

UKRI Engineering and Physical Sciences Research Council

University of BRISTOL
EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science

DSM

Aims and Objectives

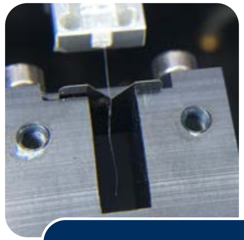
Aims

- To improve wettability and adhesion of Dyneema® fibres for improved mechanical performance of composites incorporating these fibers as reinforcement

Objectives

- The surface of Dyneema fibres will be modified chemically by plasma treatment
- Wettability of treated fibres will be studied and compared with untreated using force tensiometer and Drop Shape Analysis (DSA)
- Single fibre testing will be conducted to measure IFSS of fibre/droplet microcomposites
- Mechanical testing of composite coupons will be conducted to determine effects of plasma treatment on ILSS
- FE analysis will be conducted to understand fibre/resin interface

Plasma Treatment
- Power
- Exposure time

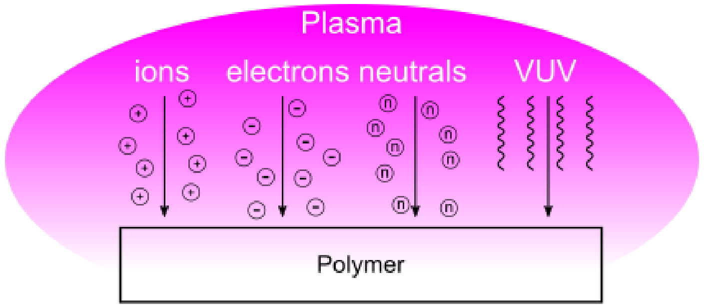


Adhesion
- IFSS

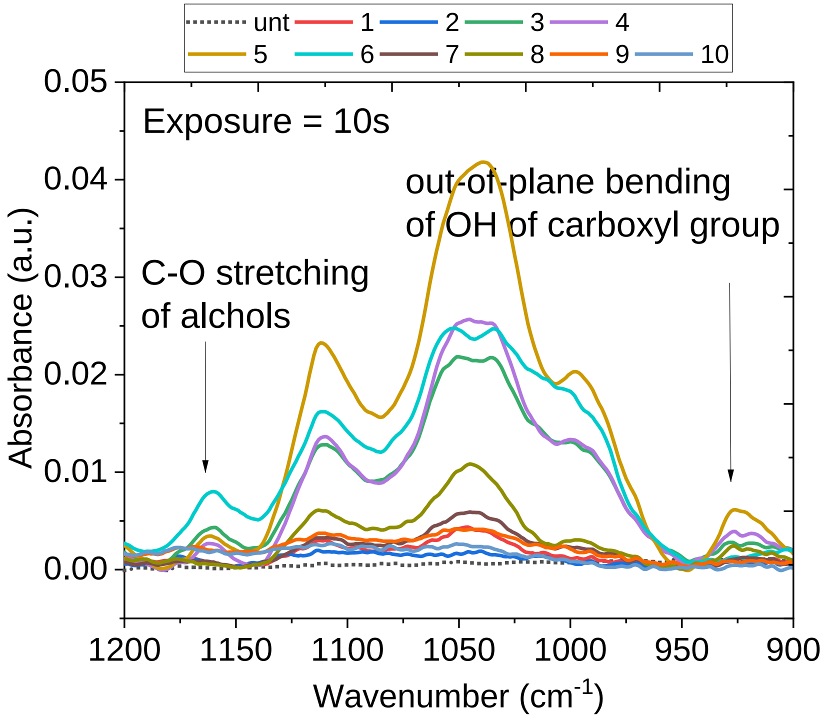
Wettability
- Drop shape analysis

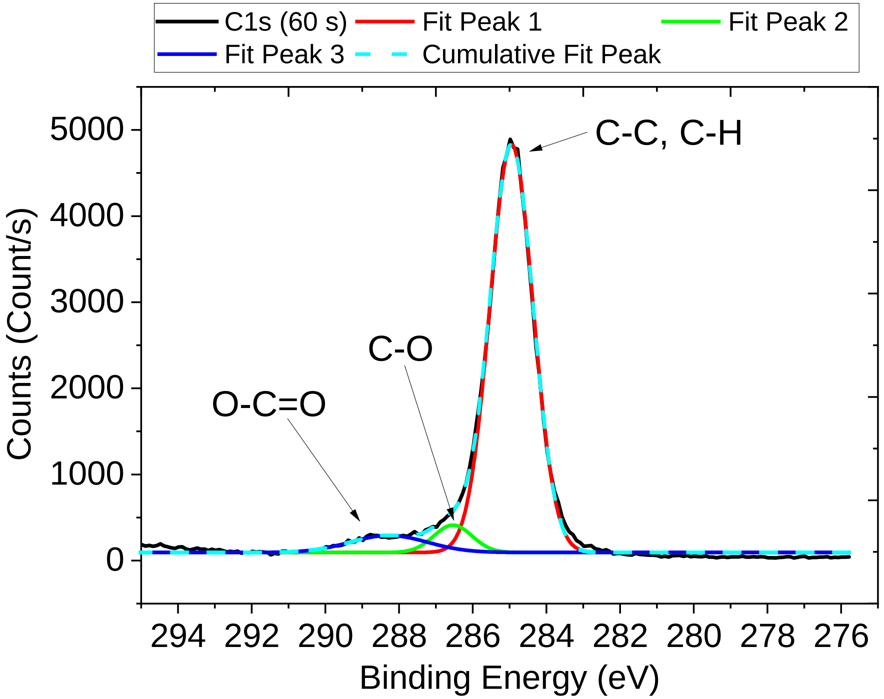
Composite Testing
- ILSS

Plasma treatment



- Scission of C-C and C-H bonds
- Addition of functional groups
  - C=C at 1647 cm^{-1}
  - C-O at 1160 cm^{-1}
  - COOH at 925 cm^{-1}
- Deconvolution of C1s after treatment shows
  - presence of C-O and O-C=O
  - Increase in oxygen functionality by 67 %





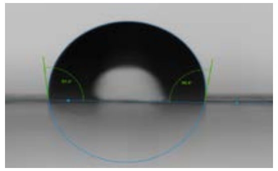
Wettability

Ownes – Wendt Model

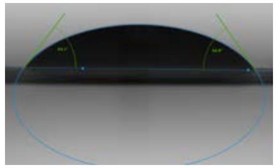
$$\boldsymbol{y = mx + b}$$

$$y = \frac{\gamma_{LV}(1+\cos\theta)}{2\sqrt{\gamma_{LV}^{D}}} \qquad \sqrt{\gamma_{SV}^{P}}\sqrt{\frac{\gamma_{LV}^{P}}{\gamma_{LV}^{D}}} + \sqrt{\gamma_{SV}^{D}}$$

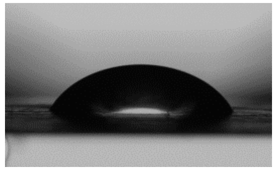
- $\boldsymbol{\gamma_{LV}^{P}}$ = polar component of liquid
- $\boldsymbol{\gamma_{LV}^{D}}$ = dispersive component of liquids
- Probe liquids of known γ_{LV}^{P} & γ_{LV}^{D} used to determine that of solid



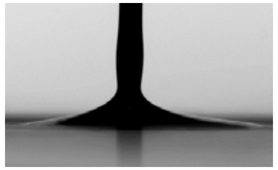
Milli Q water



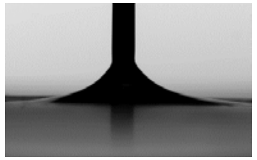
diiodomethane



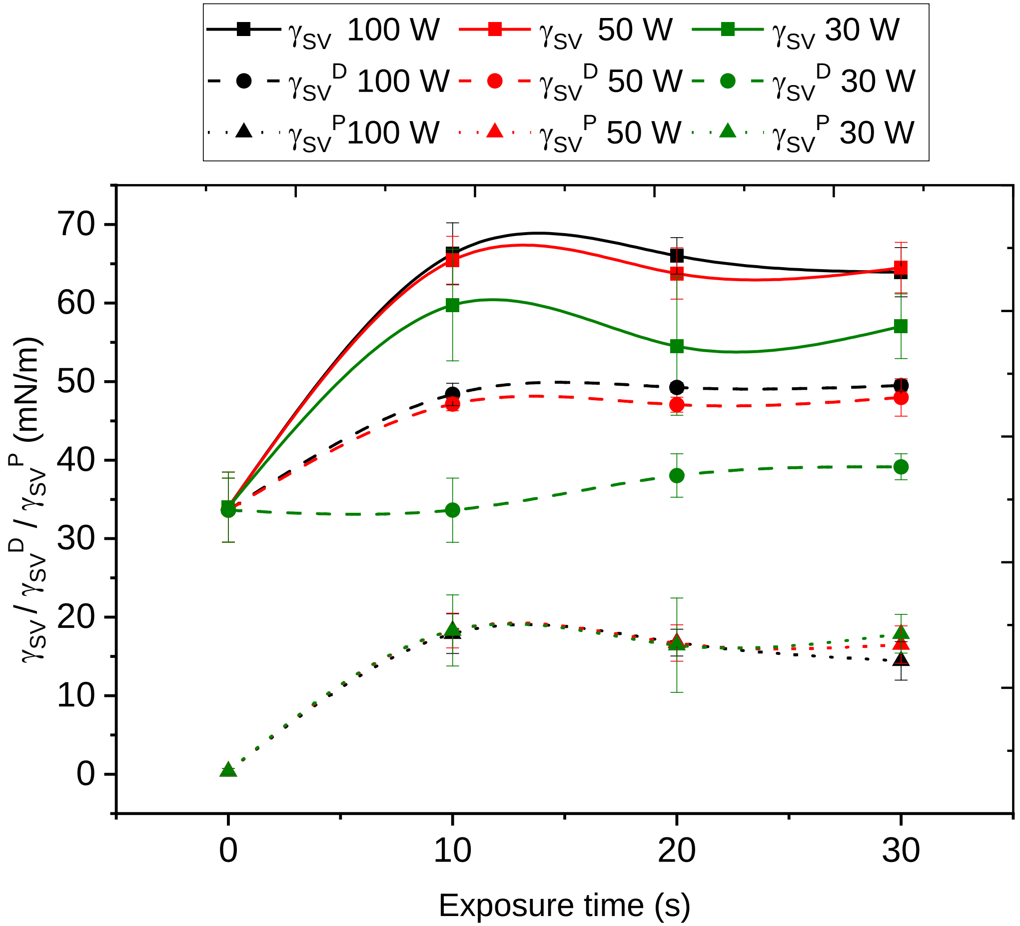
ethylene glycol



n-hexadecane

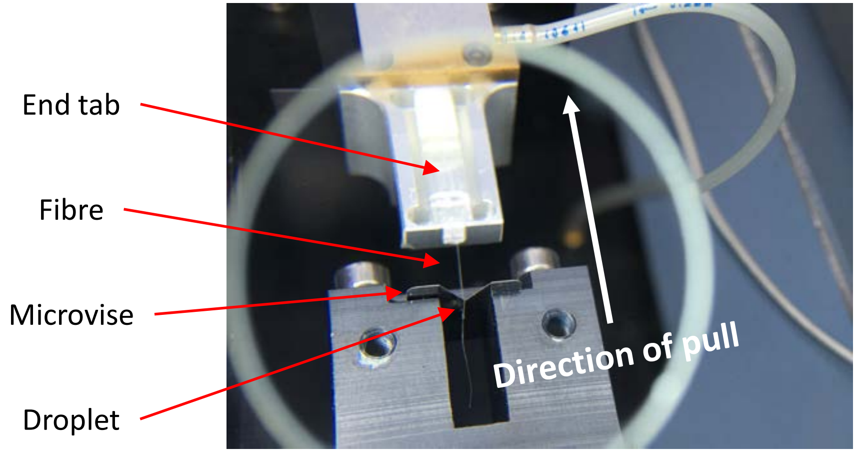


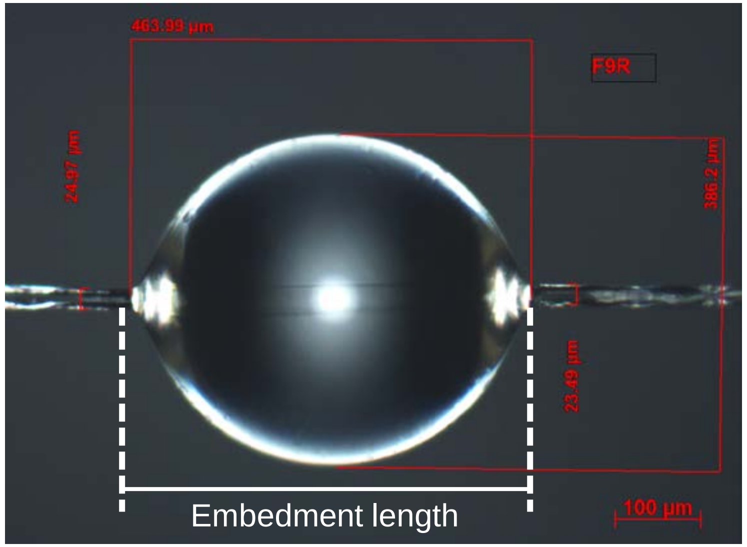
n-dodecane

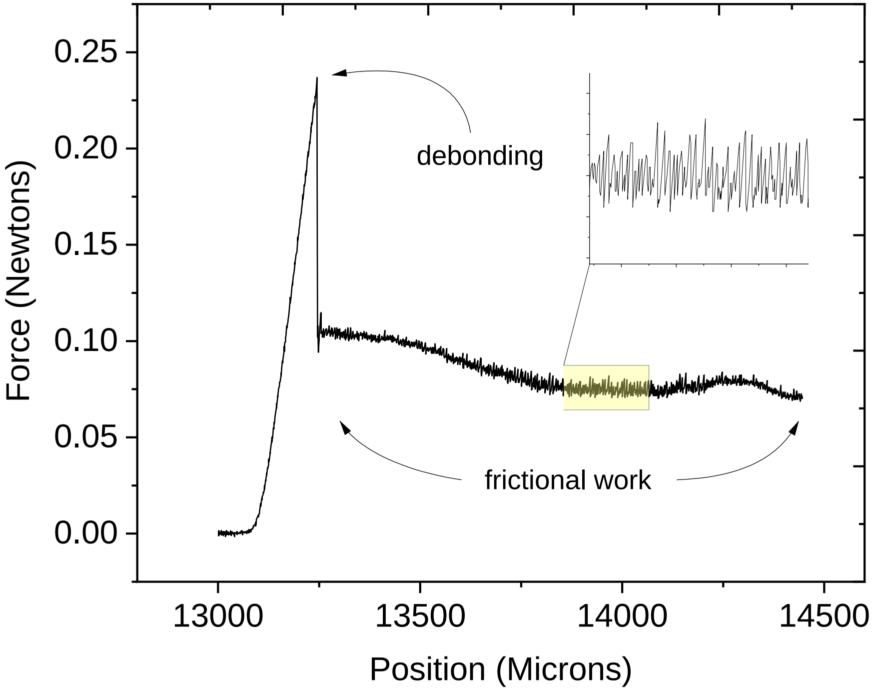


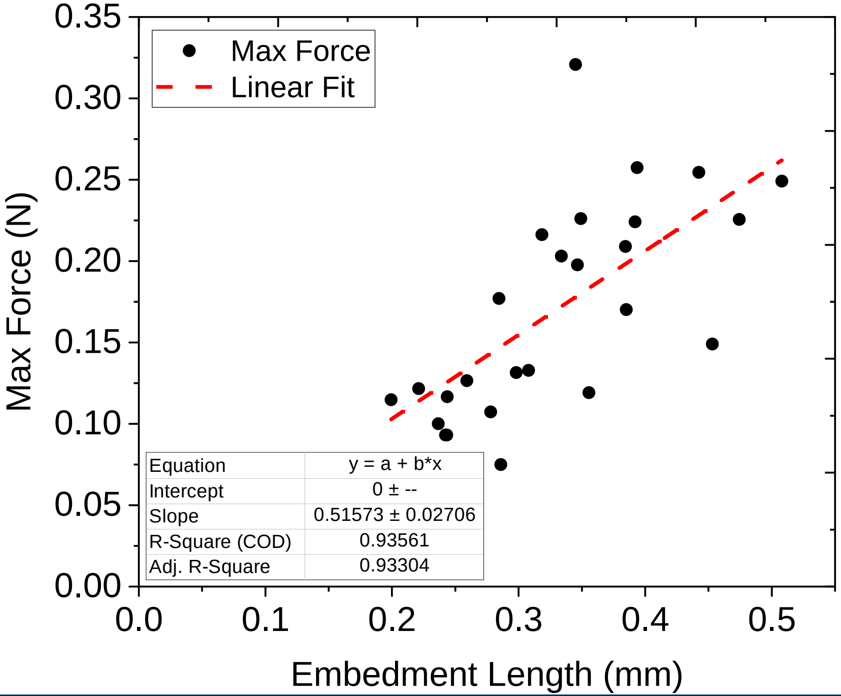
Adhesion

- Single fibre pullout test for determination of IFSS
- Droplets of resin cured on single fibres
- Cured droplets loaded along fibre axis using microvises
- Force vs displacement recorded
- IFSS (τ) determined by slope of embedment length vs max. force
- Droplets observed to have a ‘stick-and-slip’ mechanism in frictional work regime

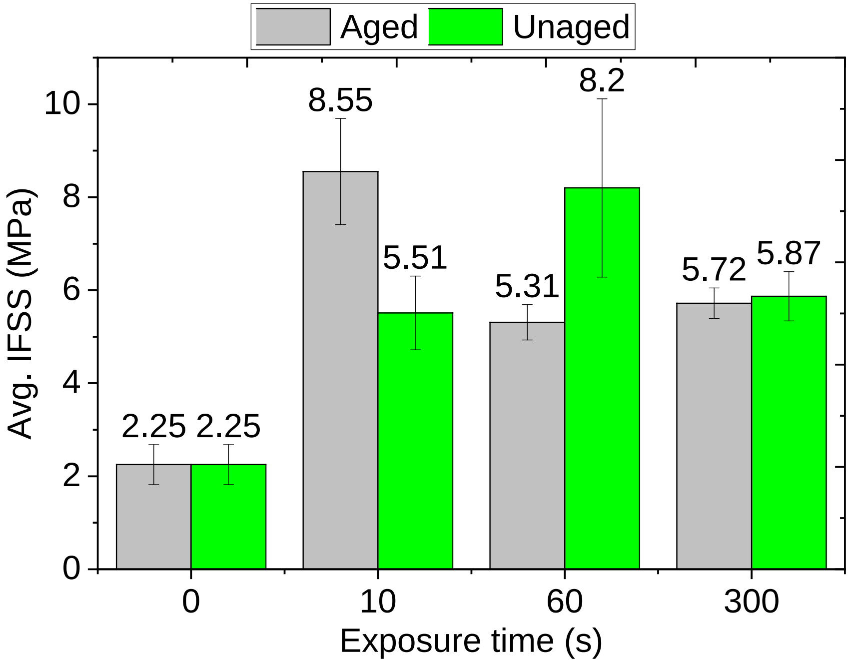


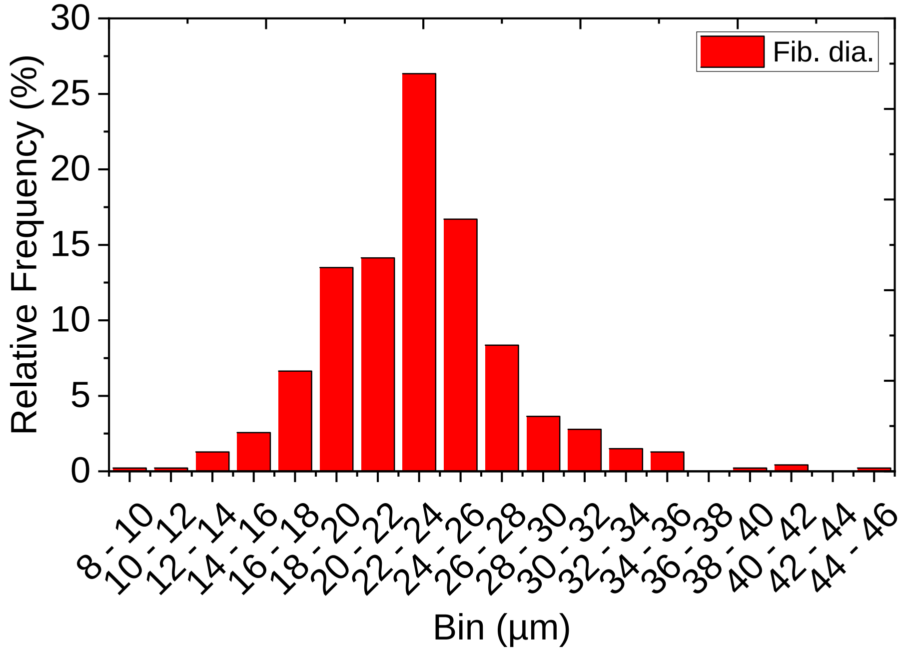


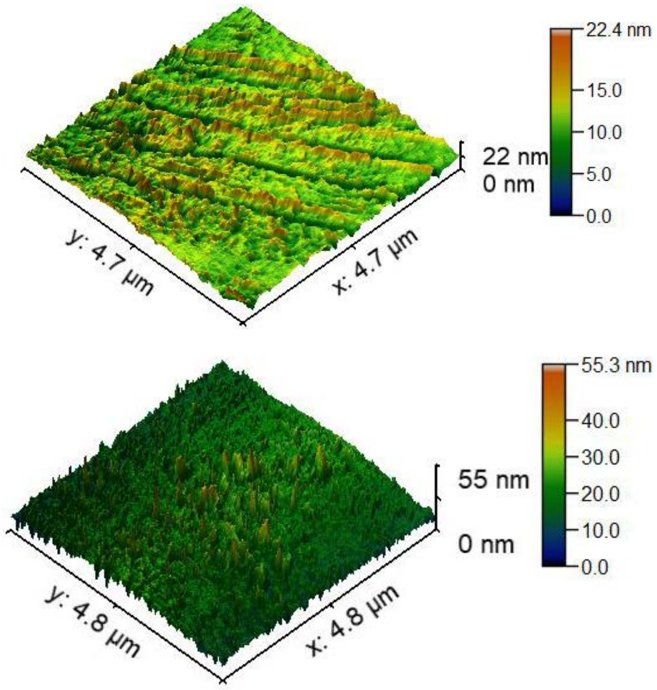




Adhesion







- **Aged:** samples tested at least 3 weeks after plasma treatment
- **Unaged:** samples tested within 24 hours after plasma treatment
- Fibre diameter can induce variability in stress calculation
- Surface area and sum of maximum peak height and maximum valley depth (Sz) increases after plasma treatment

Conclusions

Plasma treatment:

1. Causes surface modification by increase chemical functionality, surface roughness and surface area
2. Significantly increases the IFSS – towards lower exposure times
3. Increases adhesion, aged vs unaged samples show:
   a) Higher IFSS for aged sample at low exposure times
   b) Higher IFSS for unaged sample at high exposure times
4. Increases the magnitude of SFE and its components
   a) Higher effect on lower exposure times
   b) Greater effect on γ_{SV}^{P} than γ_{SV}^{D}
5. Reduces water contact angle on UHMWPE tape by 55%, changing surface's nature from hydrophobic to moderately hydrophilic

Acknowledgements

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Thank you

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