

RAPID CARBON FIBRE SURFACE PLASMA TREATMENT FOR ENHANCED FIBRE-THERMOPLASTIC INTERFACIAL PERFORMANCE

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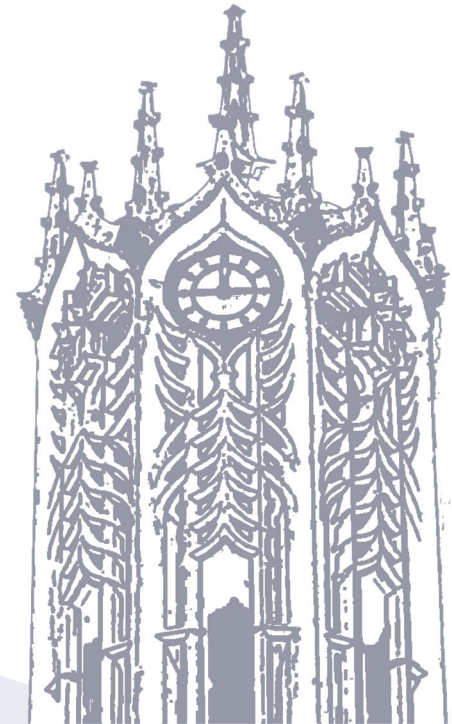
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CONTENT

1. Fibre-thermoplastic interface
2. Atmospheric air plasma treatment
3. Morphology, functionality and strength
4. Conclusions

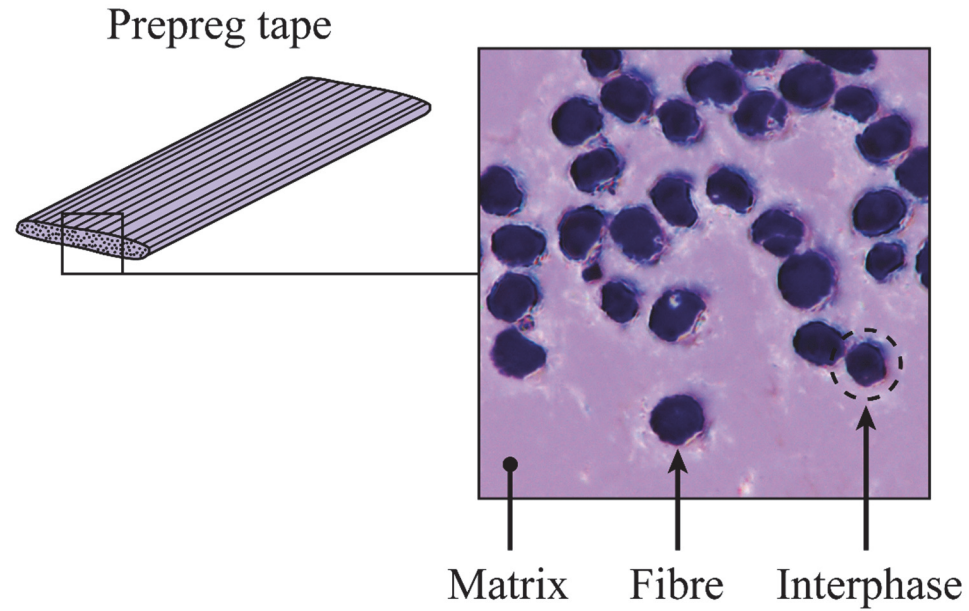


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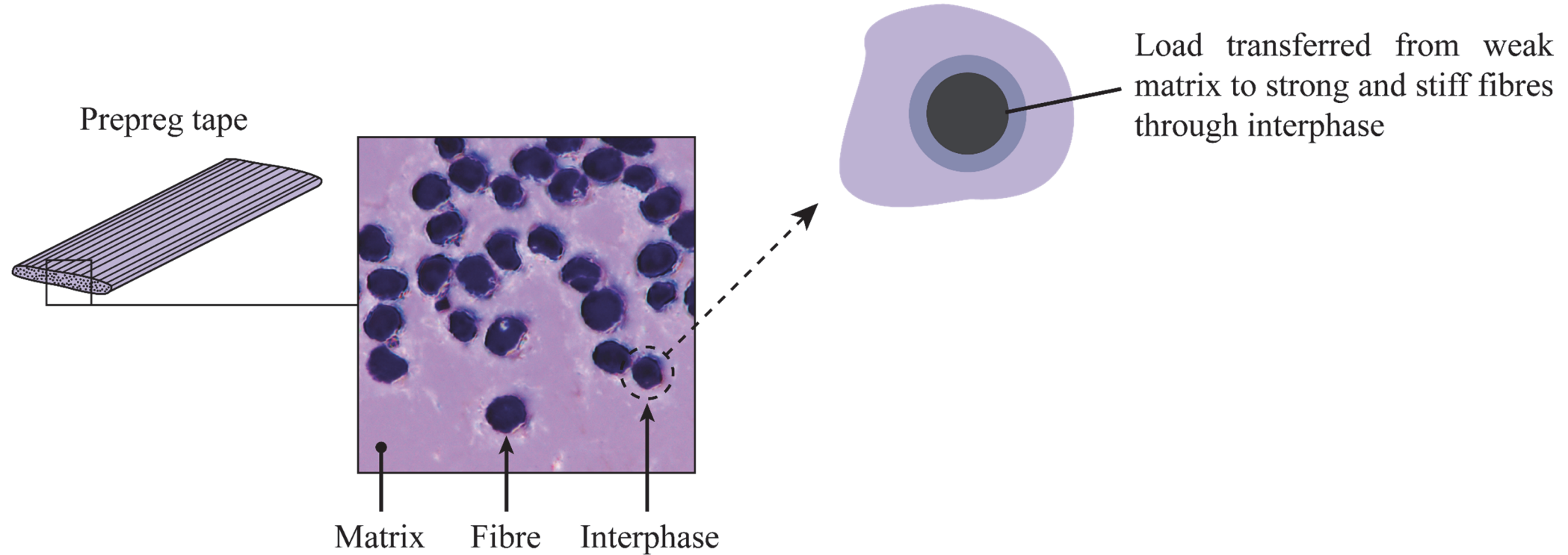


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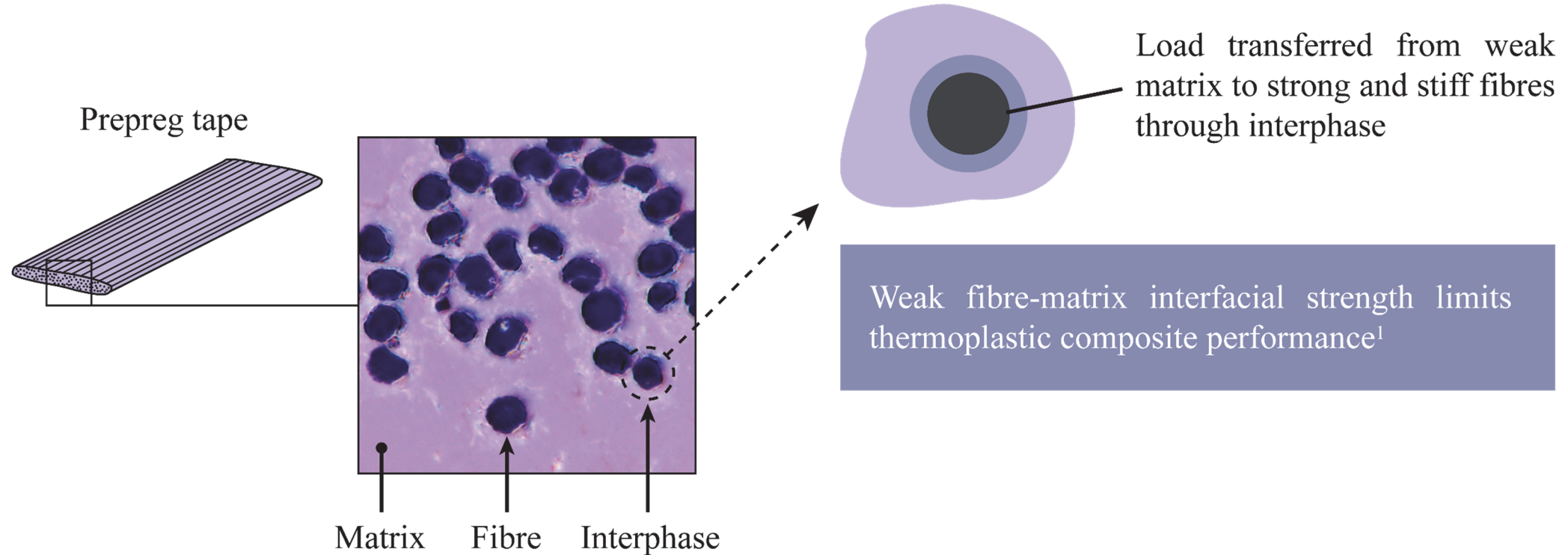
Motivation – Fibre reinforced thermoplastics



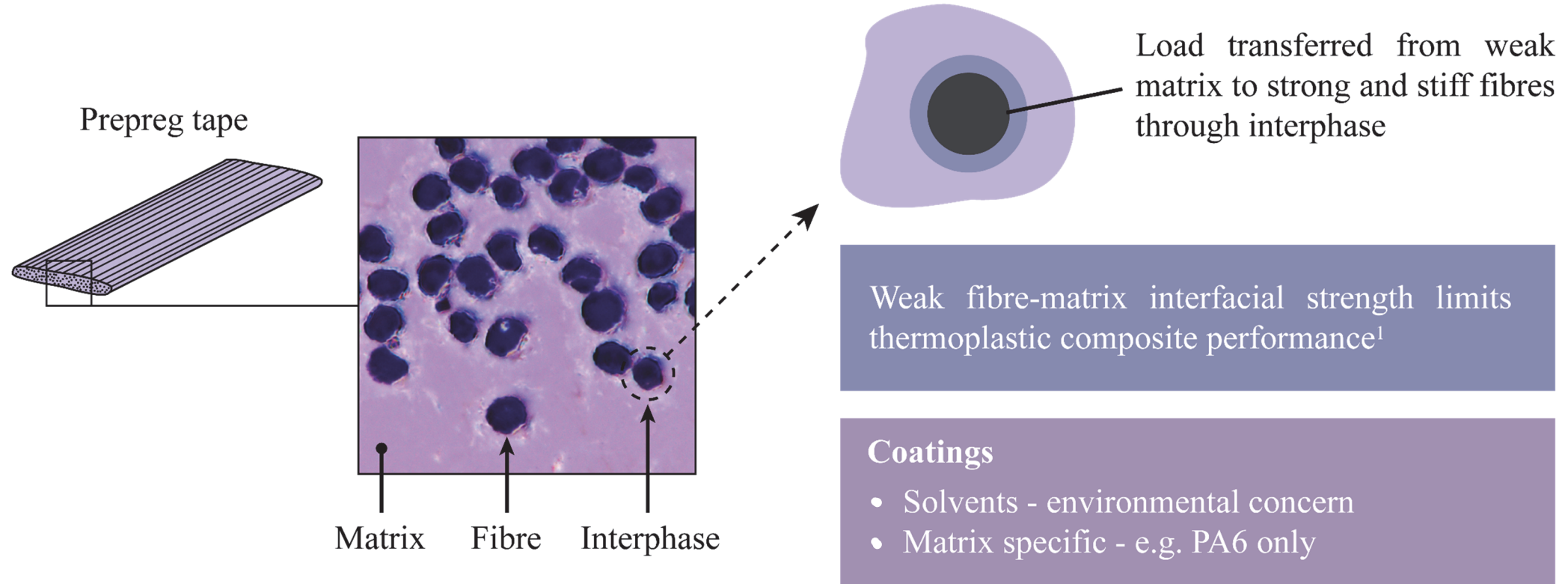
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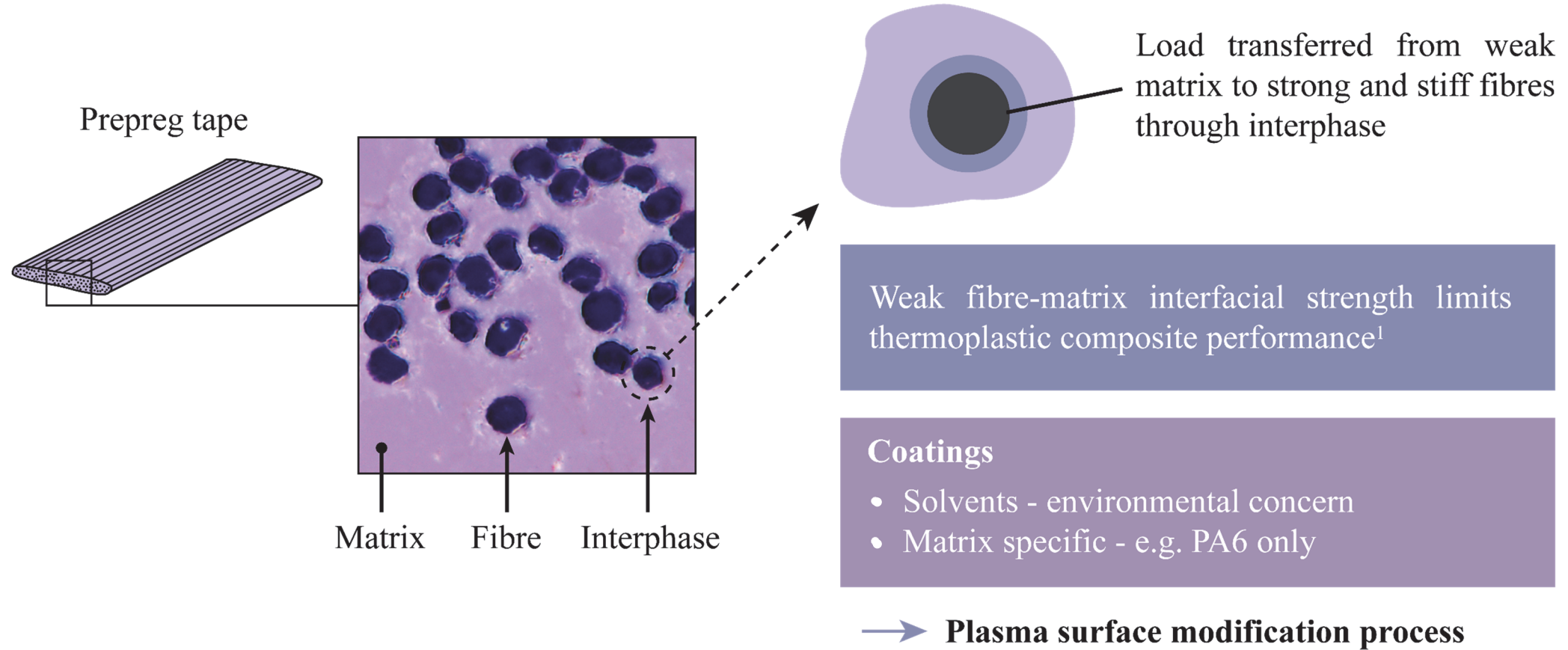
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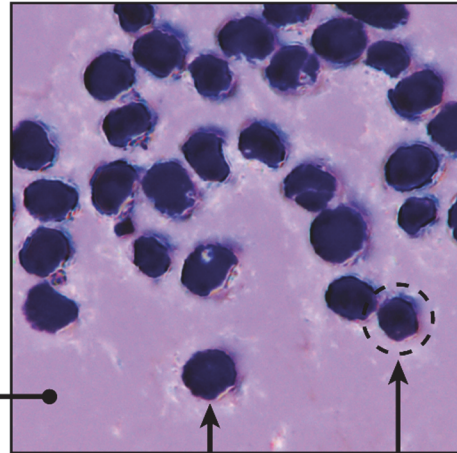


Waste polymer matrix



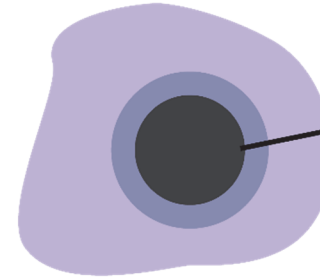
Source [2]

Can a single fibre surface treatment improve bonding with multiple thermoplastics?



Fibre

Interphase



Load transferred from weak matrix to strong and stiff fibres through interphase

Weak fibre-matrix interfacial strength limits thermoplastic composite performance¹

Coatings

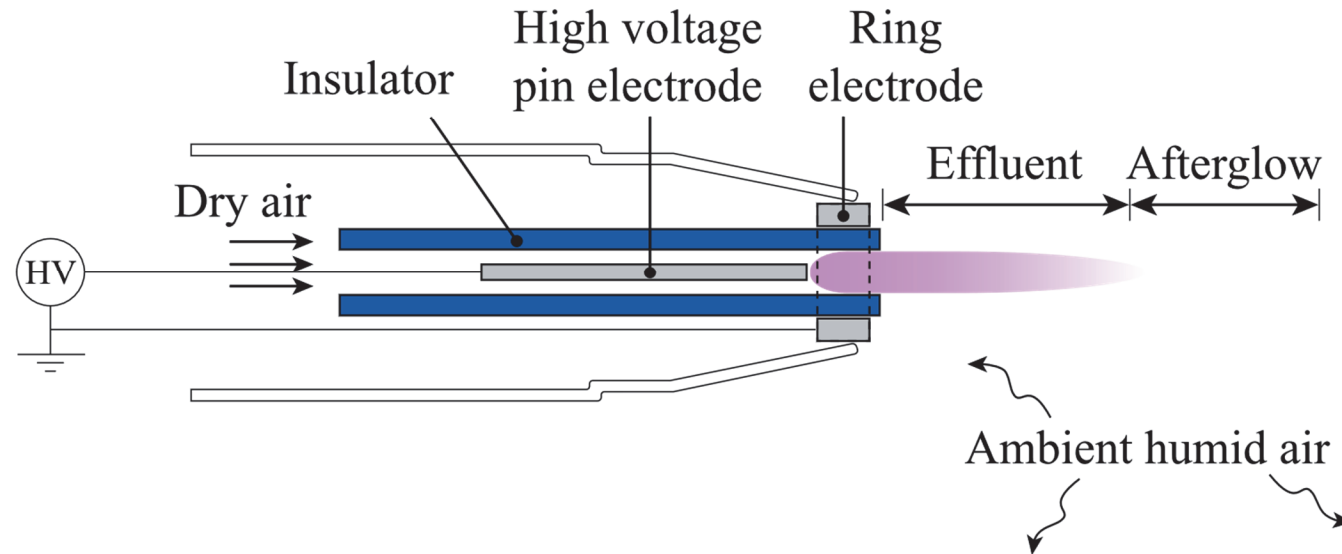
- Solvents - environmental concern
- Matrix specific - e.g. PA6 only

→ **Plasma surface modification process**

[1] Mengjin, W. U., et al. (2021). Interfacial performance of high-performance fiber-reinforced composites improved by cold plasma treatment: A review. [Online]: <https://doi.org/10.1016/j.surf.2021.101077>

[2] GlobalSpec (2020) How to recycle polymer waste. [Online]: <https://insights.globalspec.com/article/14792/how-to-recycle-polymer-waste>

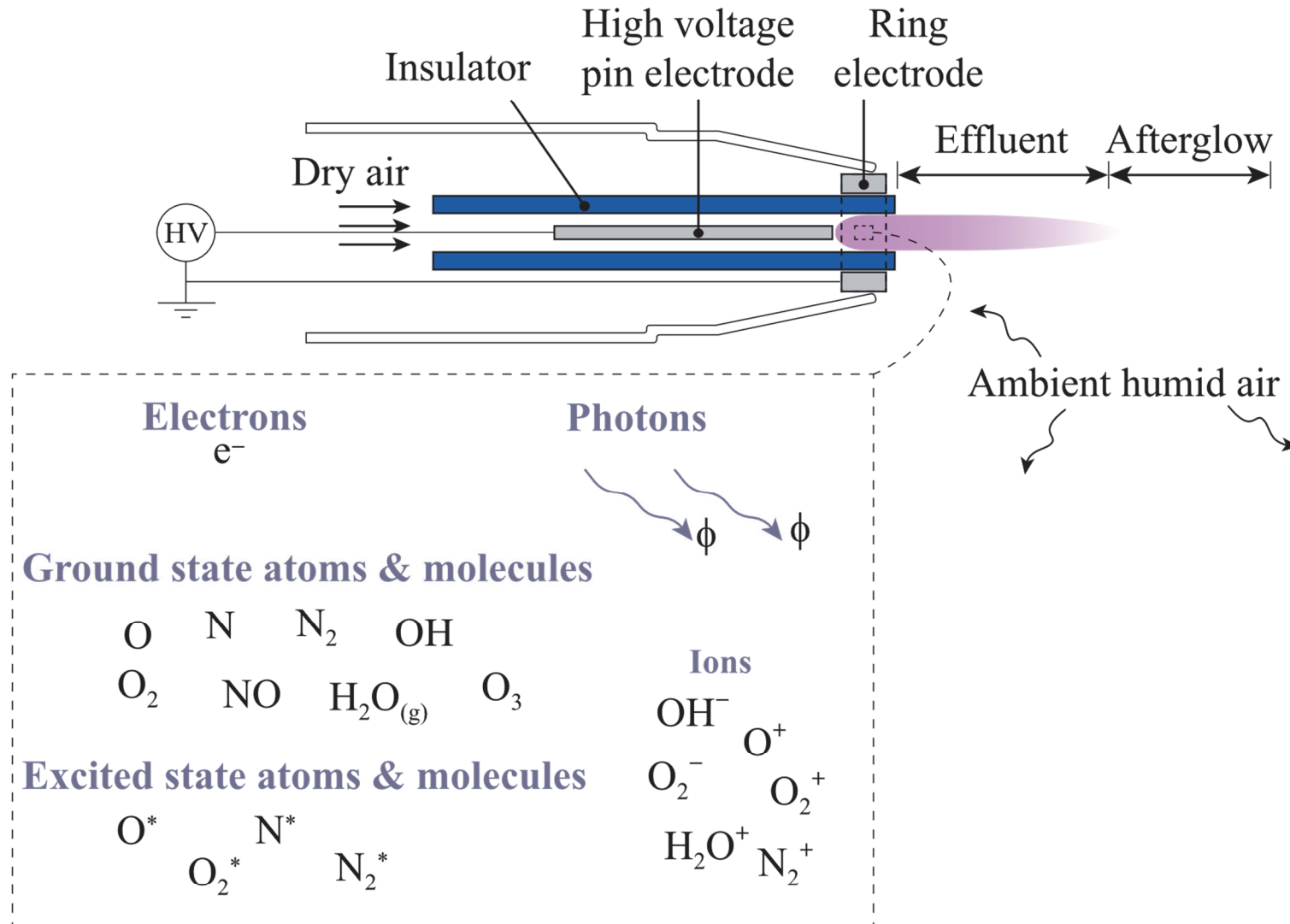
Motivation – Atmospheric pressure plasma jet treatment



[1] Becker, Kurt H., et al. (2004), eds. *Non-equilibrium air plasmas at atmospheric pressure*. CRC press.

[2] Lu, X., et al. (2016). Reactive species in non-equilibrium atmospheric-pressure plasmas: Generation, transport, and biological effects. *Physics Reports* 630. – Online: <https://doi.org/10.1016/j.physrep.2016.03.003>

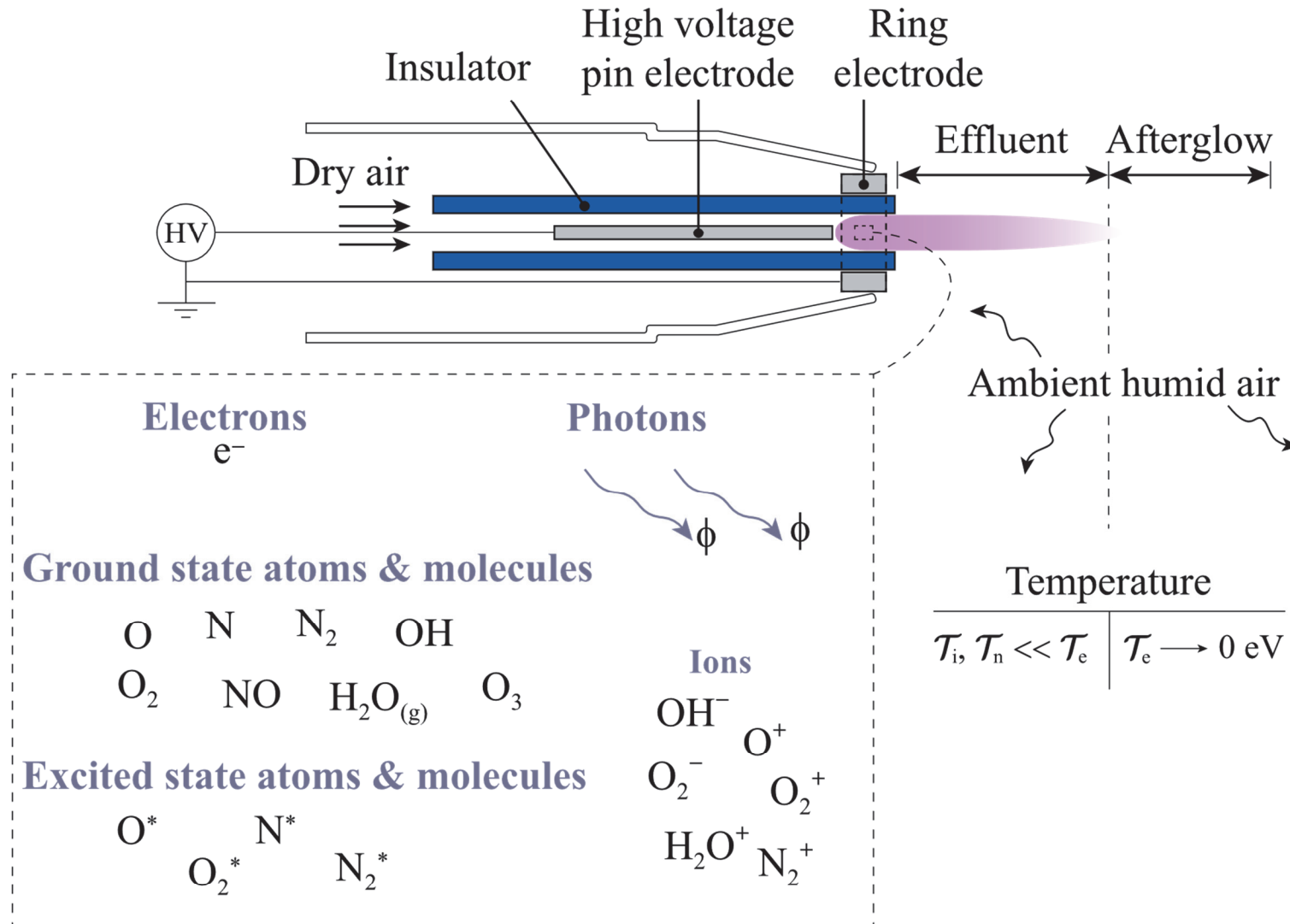
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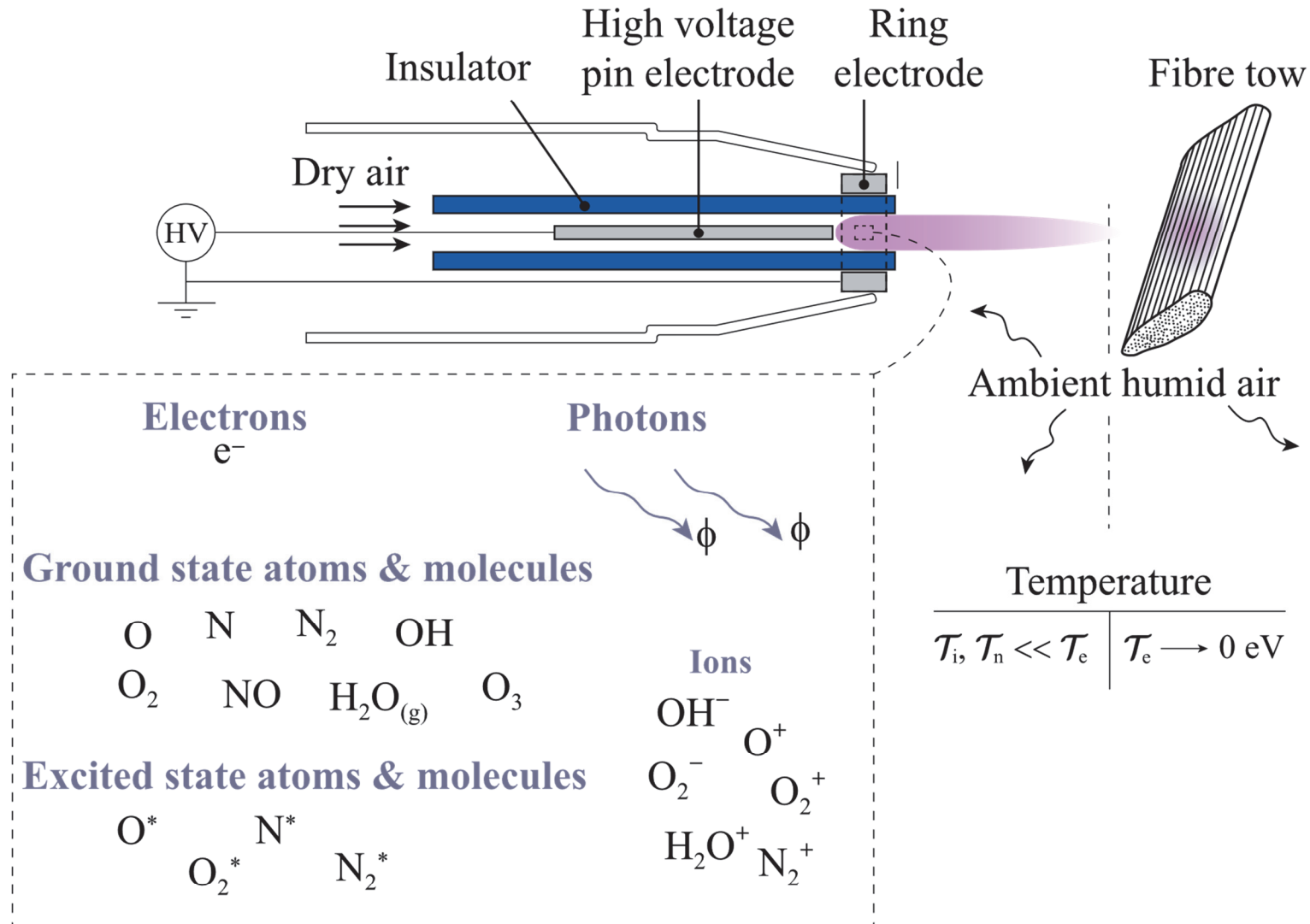
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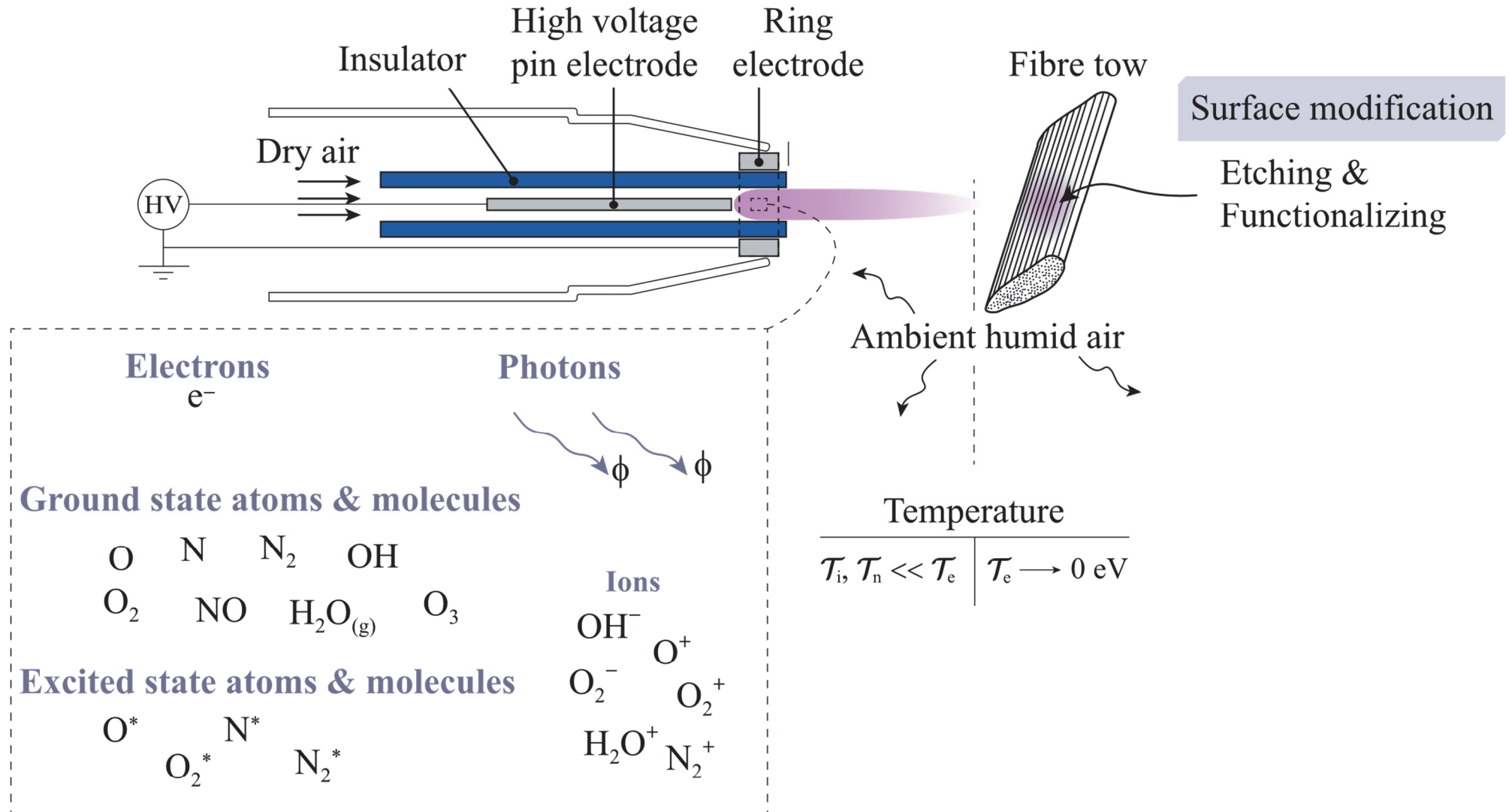
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Motivation – Atmospheric pressure plasma jet treatment



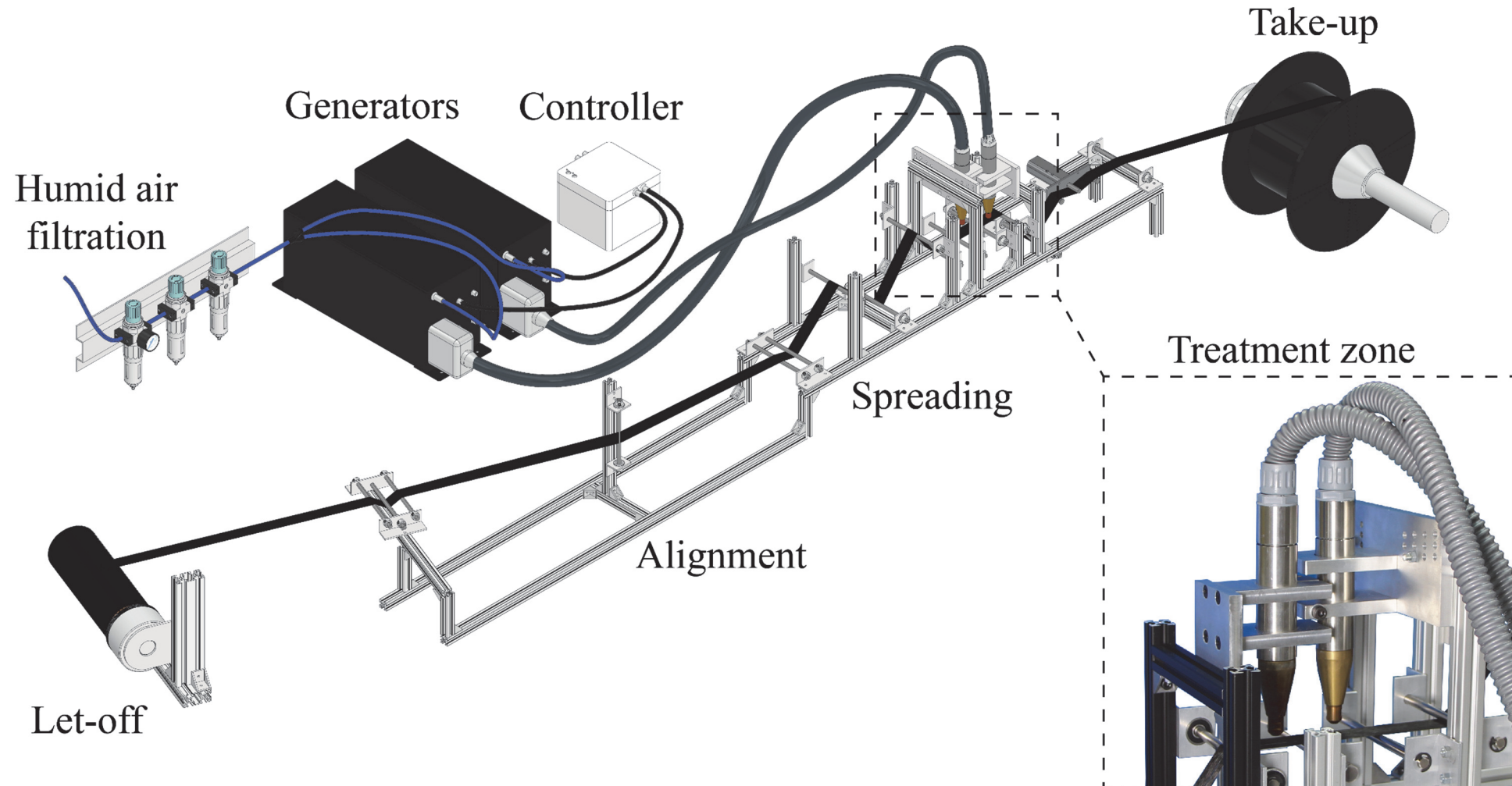
[1] Becker, Kurt H., et al. (2004), eds. *Non-equilibrium air plasmas at atmospheric pressure*. CRC press.

[2] Lu, X., et al. (2016). Reactive species in non-equilibrium atmospheric-pressure plasmas: Generation, transport, and biological effects. *Physics Reports* 630. – Online: <https://doi.org/10.1016/j.physrep.2016.03.003>

Continuous plasma treatment



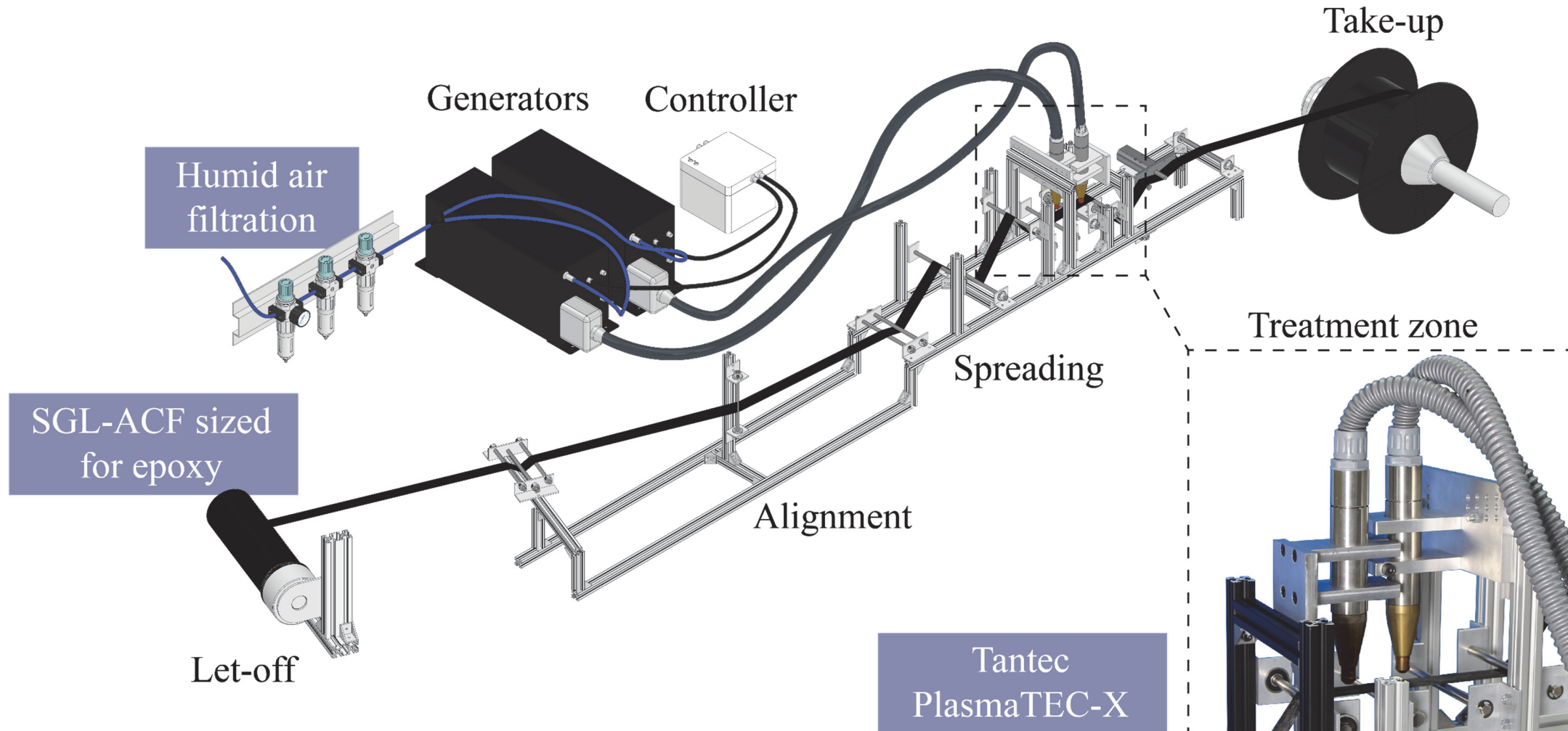
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Continuous plasma treatment



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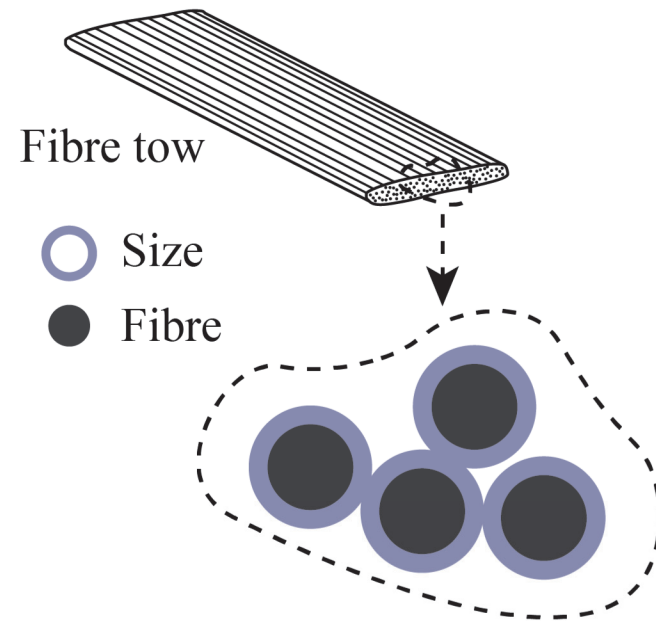


Surface modification - Morphology



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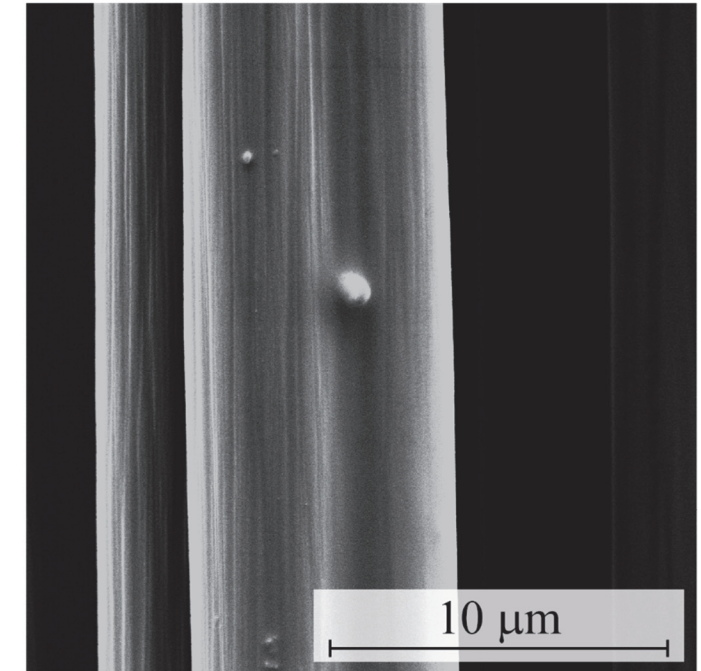
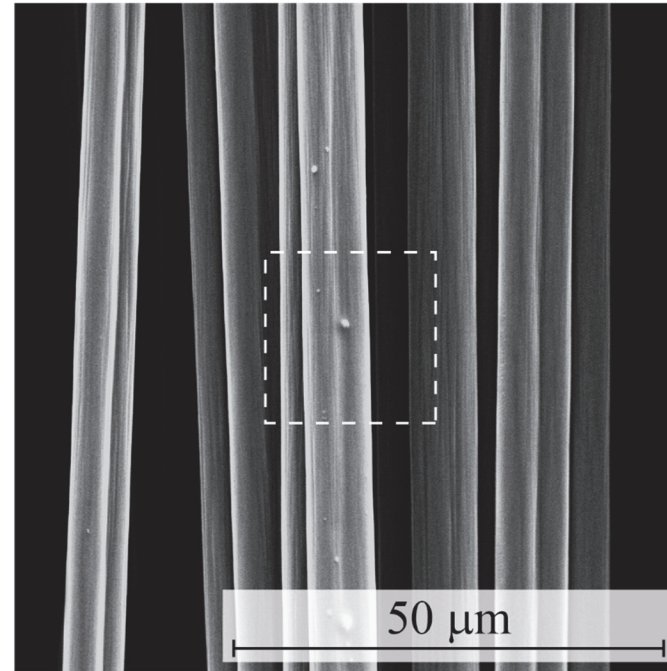
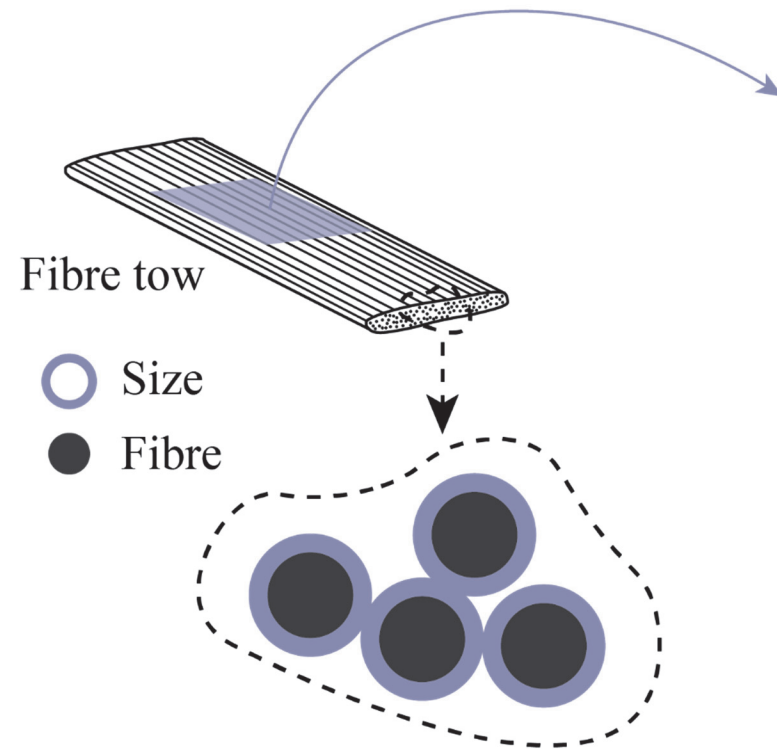
Carbon fibre size



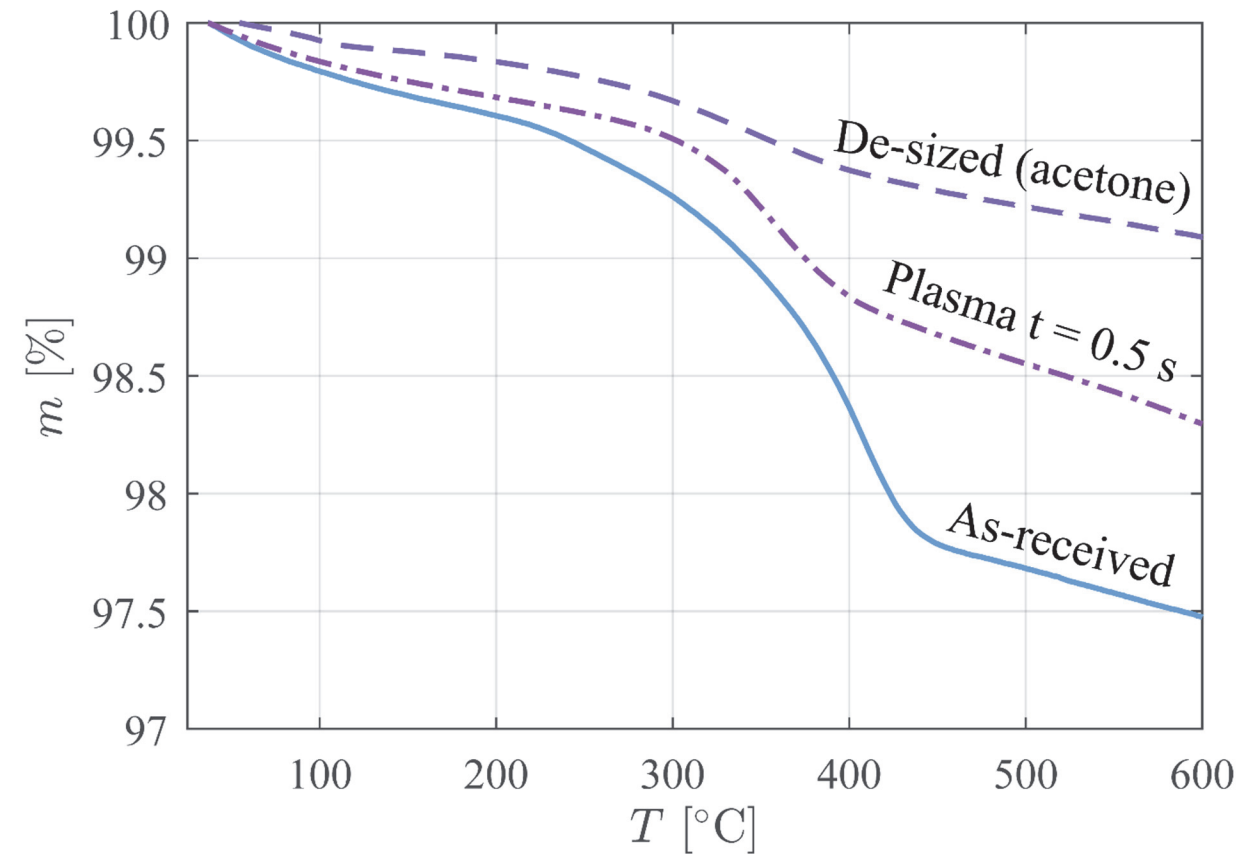
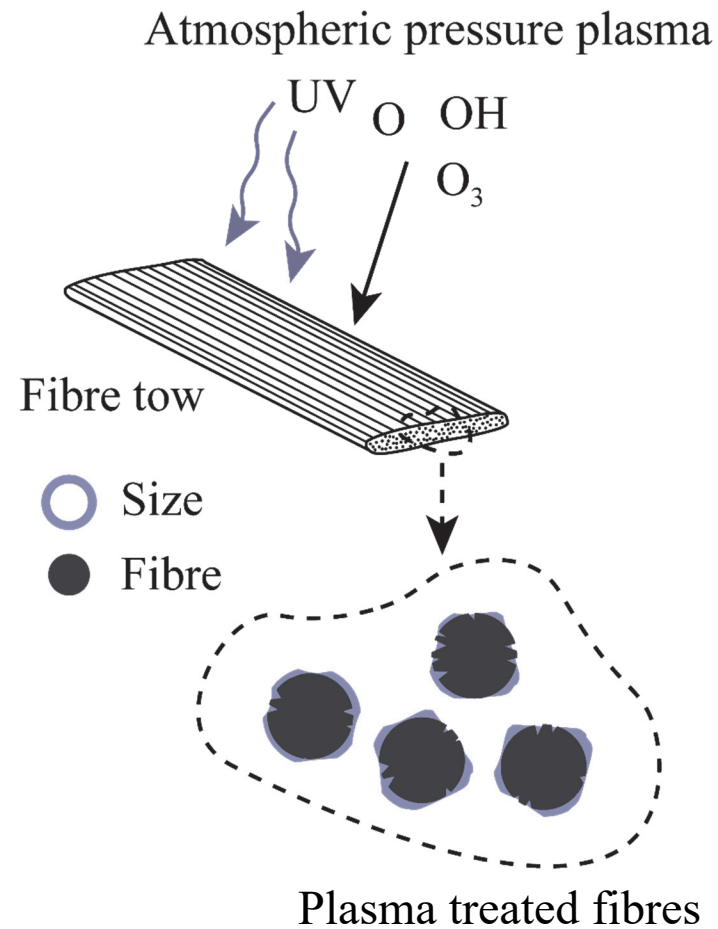
Carbon fibre size – SEM



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Carbon fibre size – Nitrogen atmosphere TGA



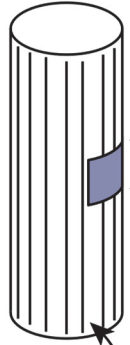
Roughened plasma treated surface – SEM



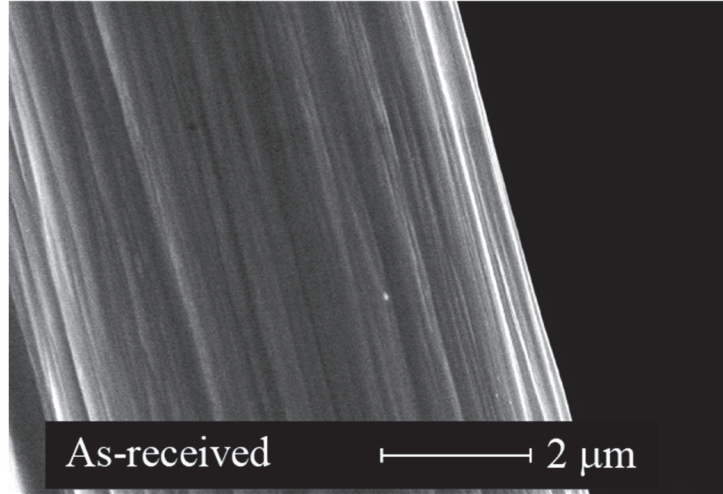
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Carbon fibre



Carbonized PAN
precursor tracks



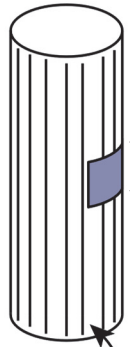
Roughened plasma treated surface – SEM



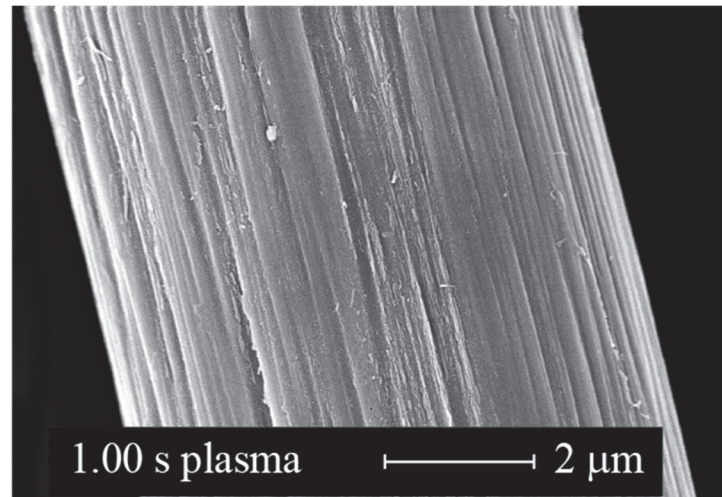
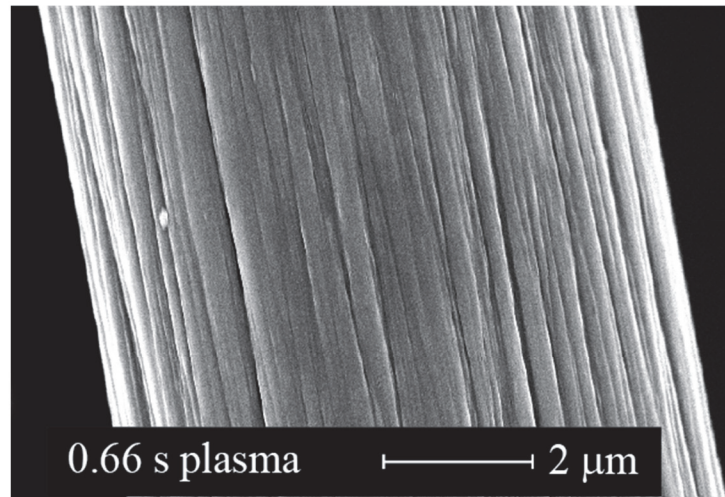
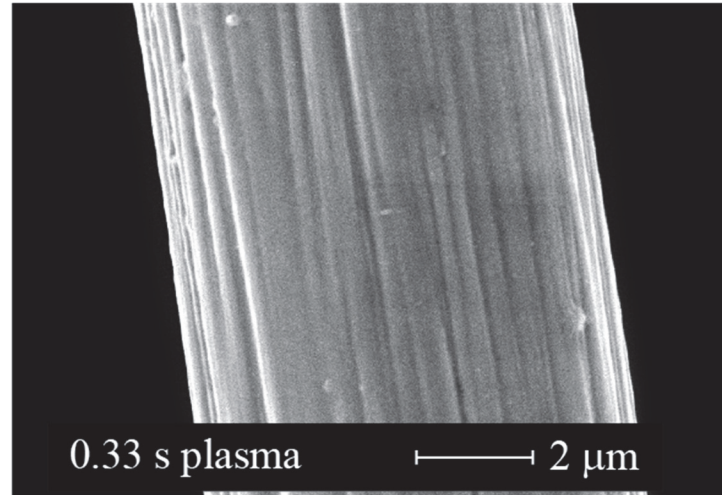
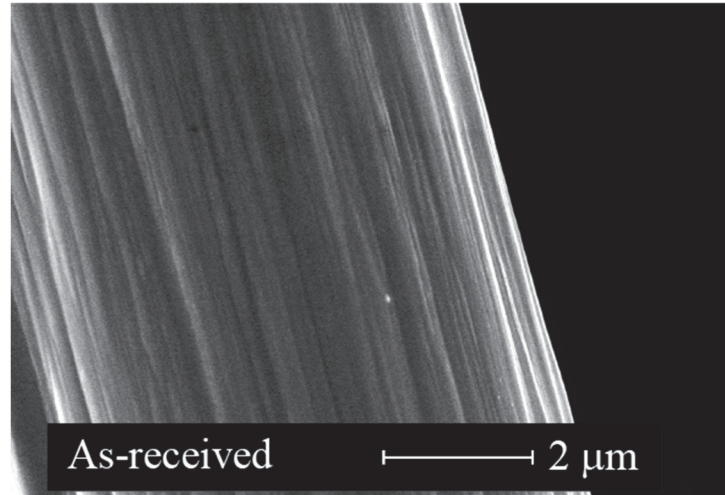
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Carbon fibre



Carbonized PAN
precursor tracks



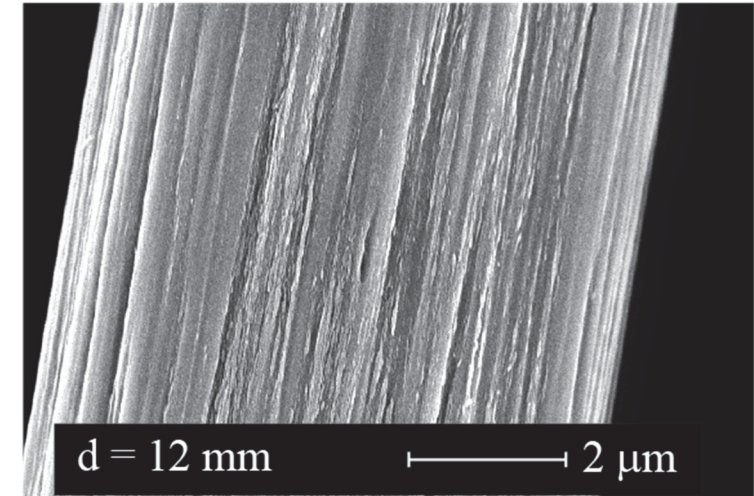
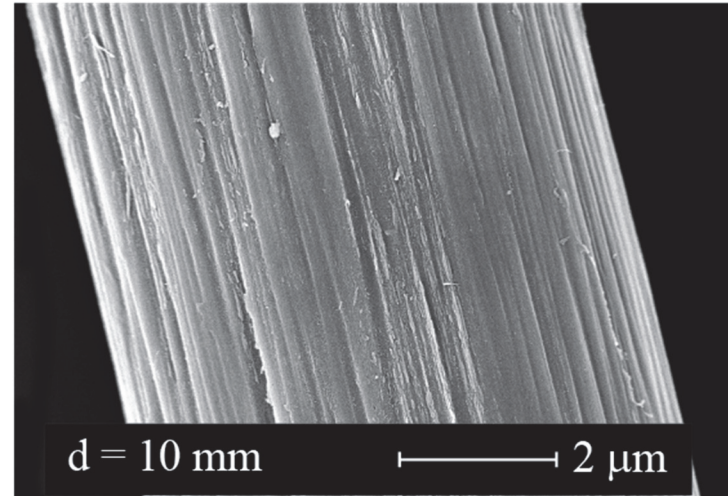
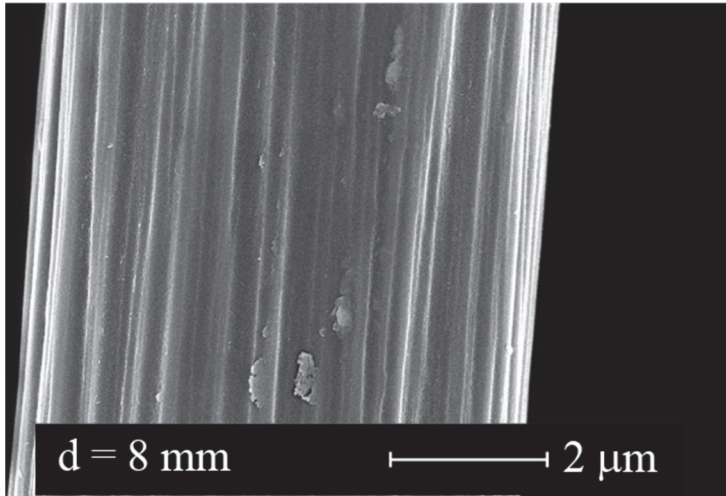
Roughened plasma treated surface – SEM



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Increasing nozzle-fibre distance →

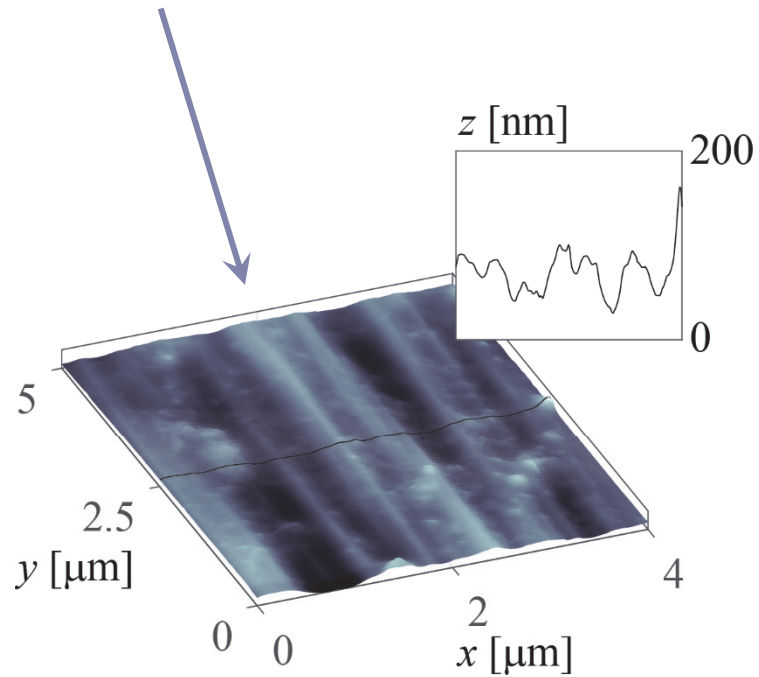


All treated for 1 second

Roughened plasma treated surface – AFM



Tilt and curvature corrected



As-received, $S_q = 22 \text{ nm}$

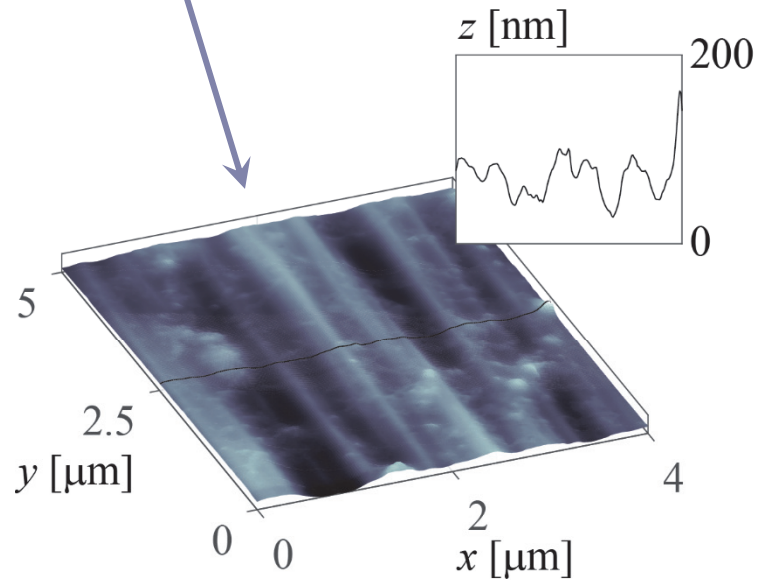
Roughened plasma treated surface – AFM



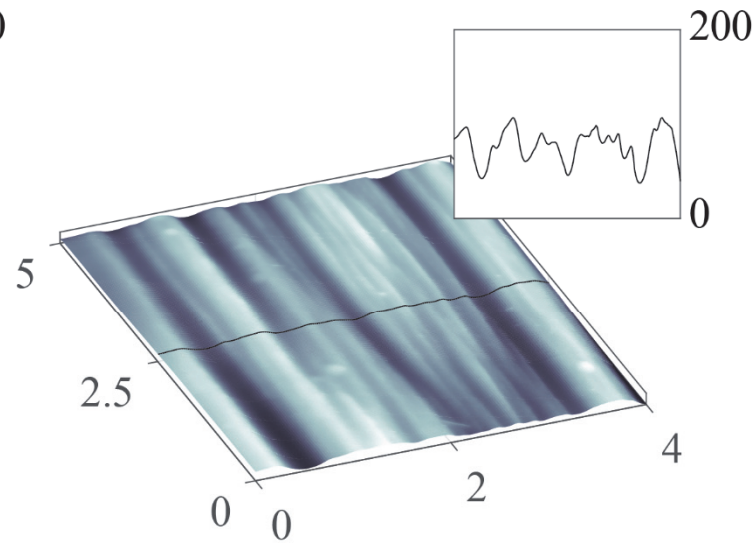
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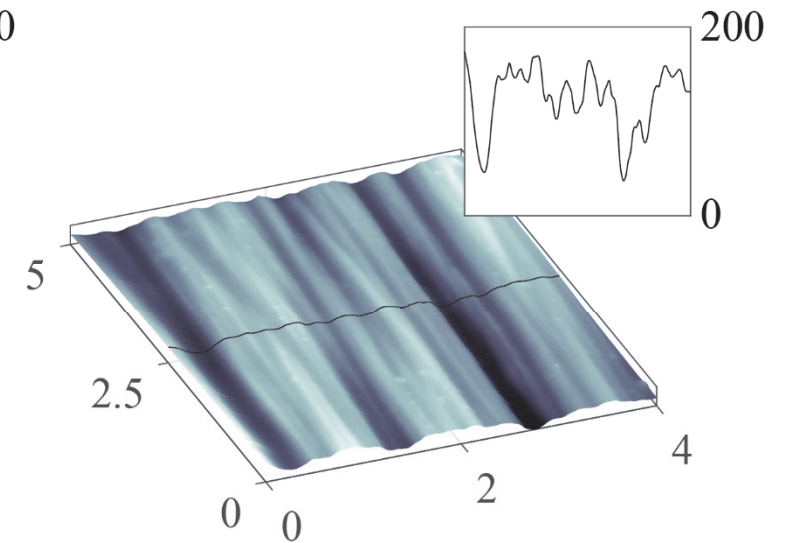
Tilt and curvature corrected



As-received, $S_q = 22$ nm

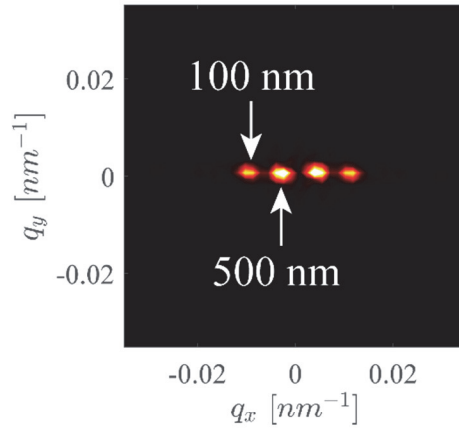


Desized, $S_q = 20.82$ nm

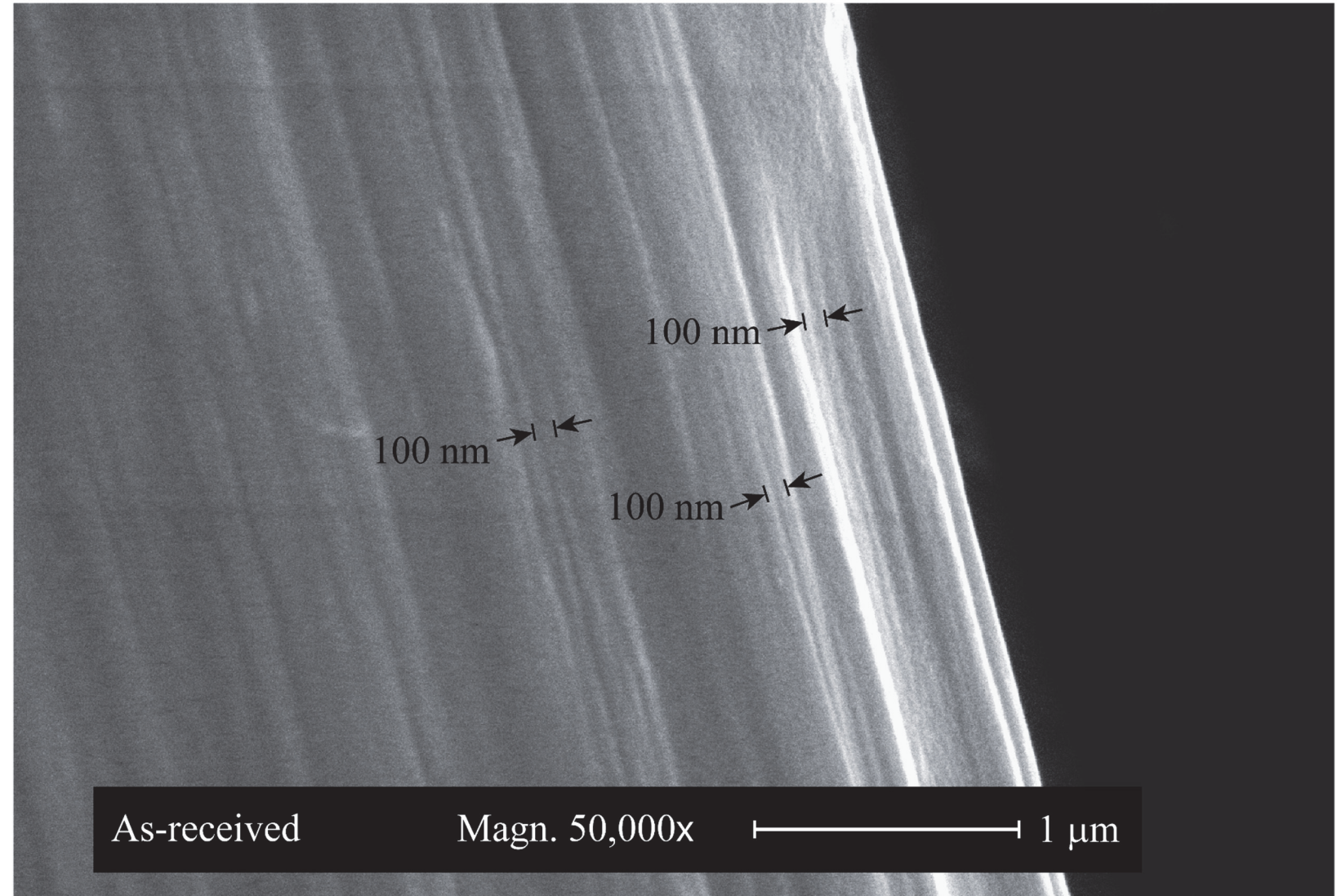


$d = 10$ mm, $t = 1$ s, $S_q = 34.9$ nm

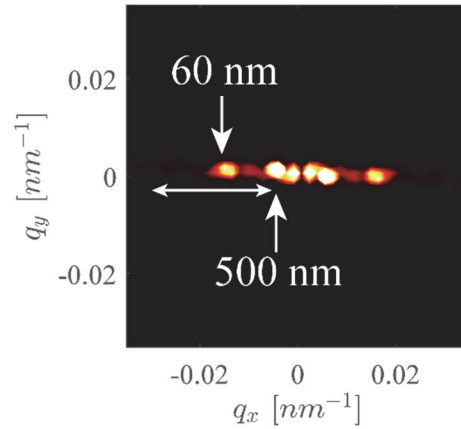
2D PSD interpretation with SEM image – As-received



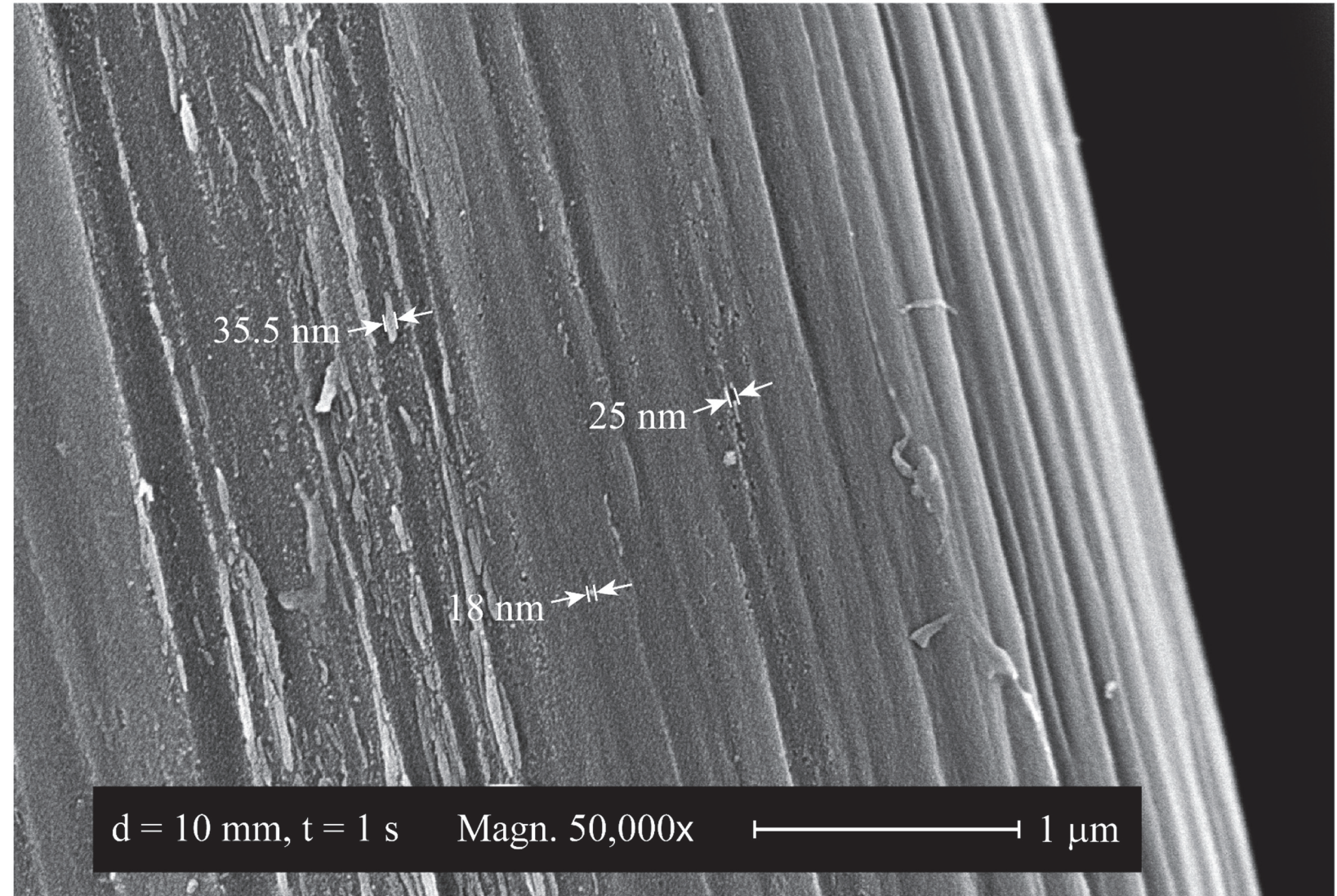
As-received, Sq = 22 nm



2D PSD interpretation with SEM image – Plasma treated



$d = 10 \text{ mm}$, $t = 1 \text{ s}$, $Sq = 34.9 \text{ nm}$

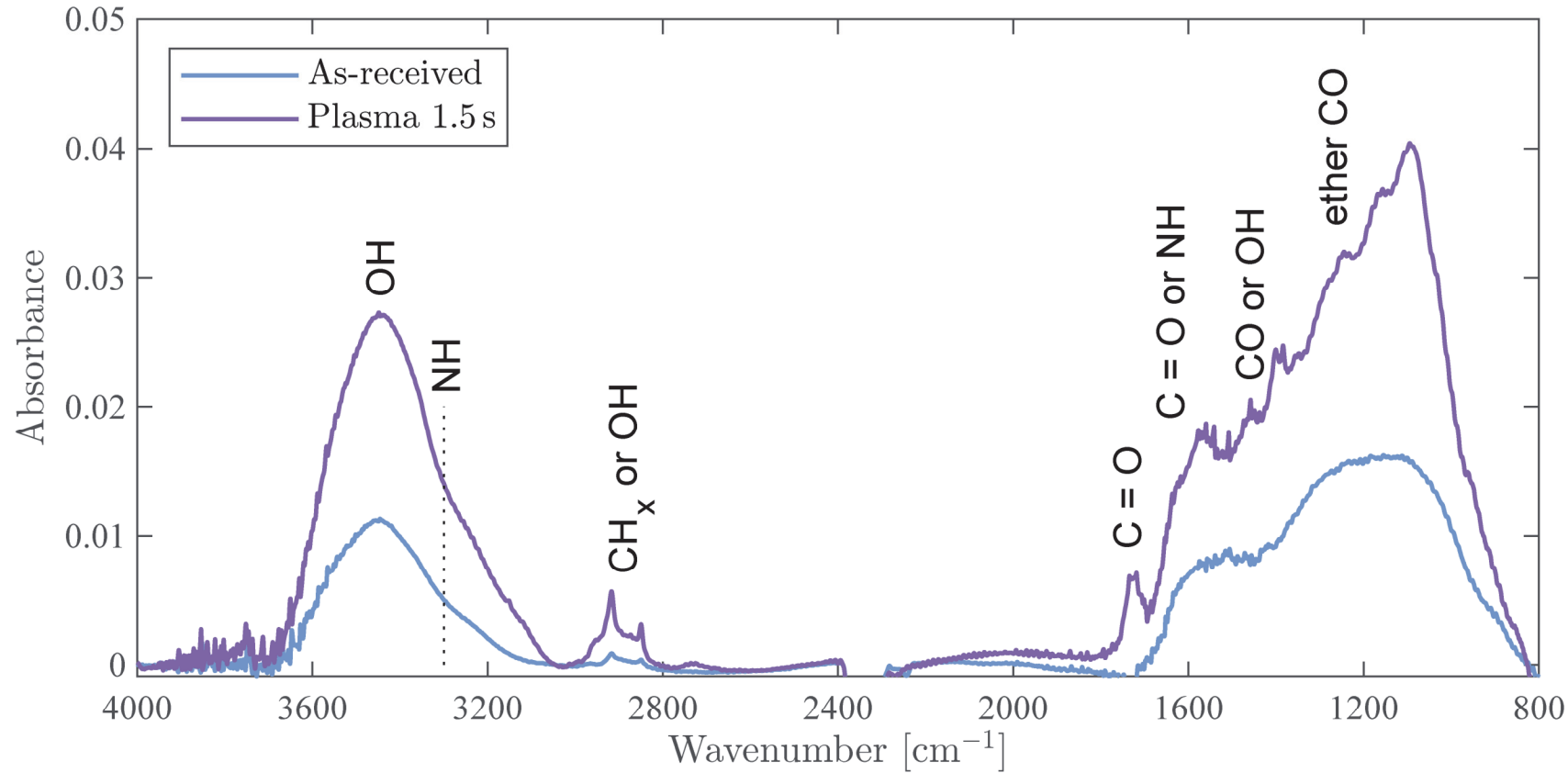


Surface modification - Functionalisation



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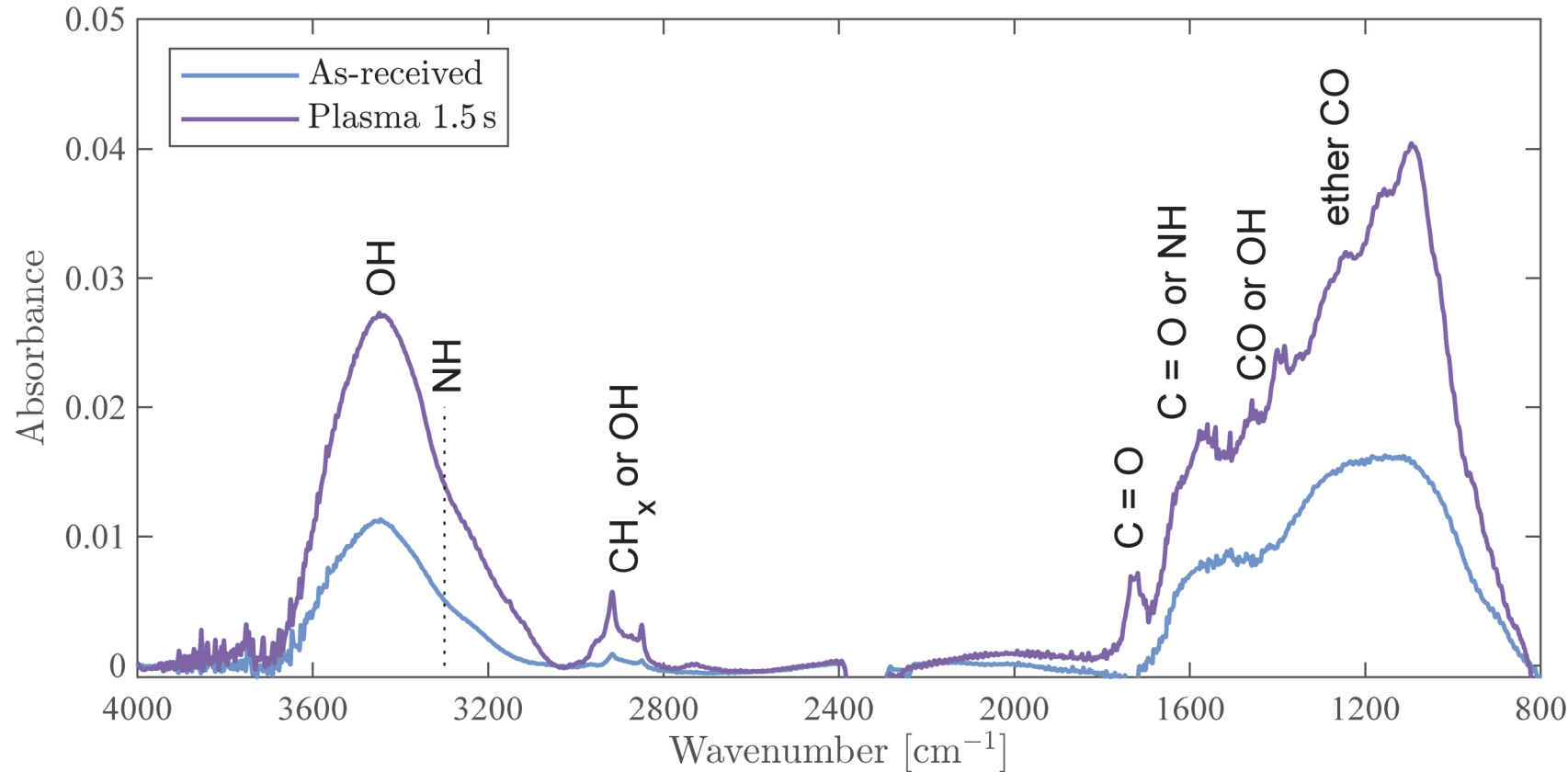
Surface modification – Transmission KBr FT-IR



Surface modification – Transmission KBr FT-IR

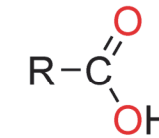


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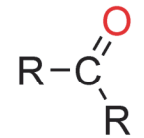


Expected functionality

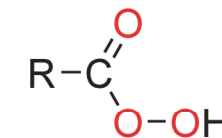
Carboxylic acid



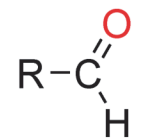
Ketone



Peroxy acid



Aldehyde



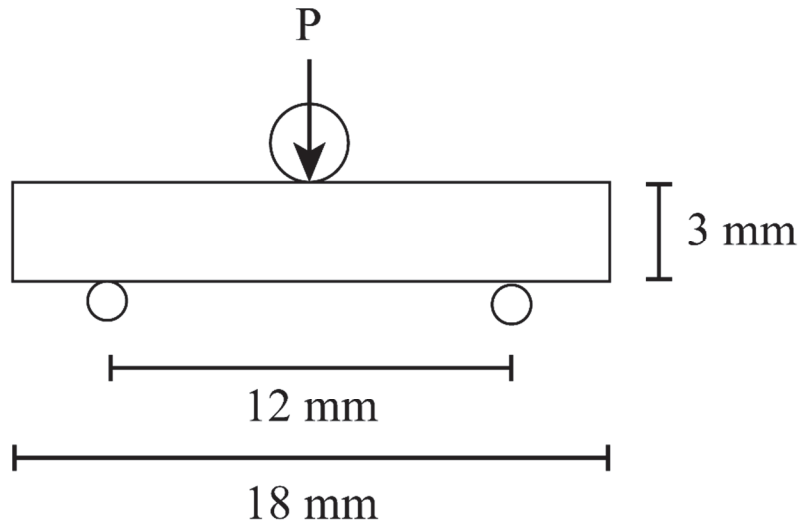
... no surprises.

Surface modification – Short beam strength



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Short beam strength - method



ASTM D2344

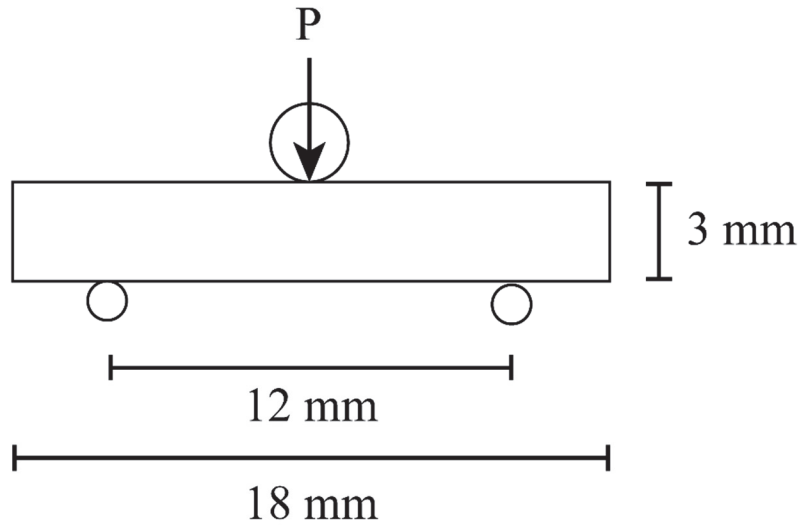
$$\sigma_{SBS} = 0.75 \times \frac{P_m}{b \times h}$$

P_m Maximum force

b Width

h Thickness

Short beam strength – failure mode



ASTM D2344

$$\sigma_{SBS} = 0.75 \times \frac{P_m}{b \times h}$$

P_m Maximum force

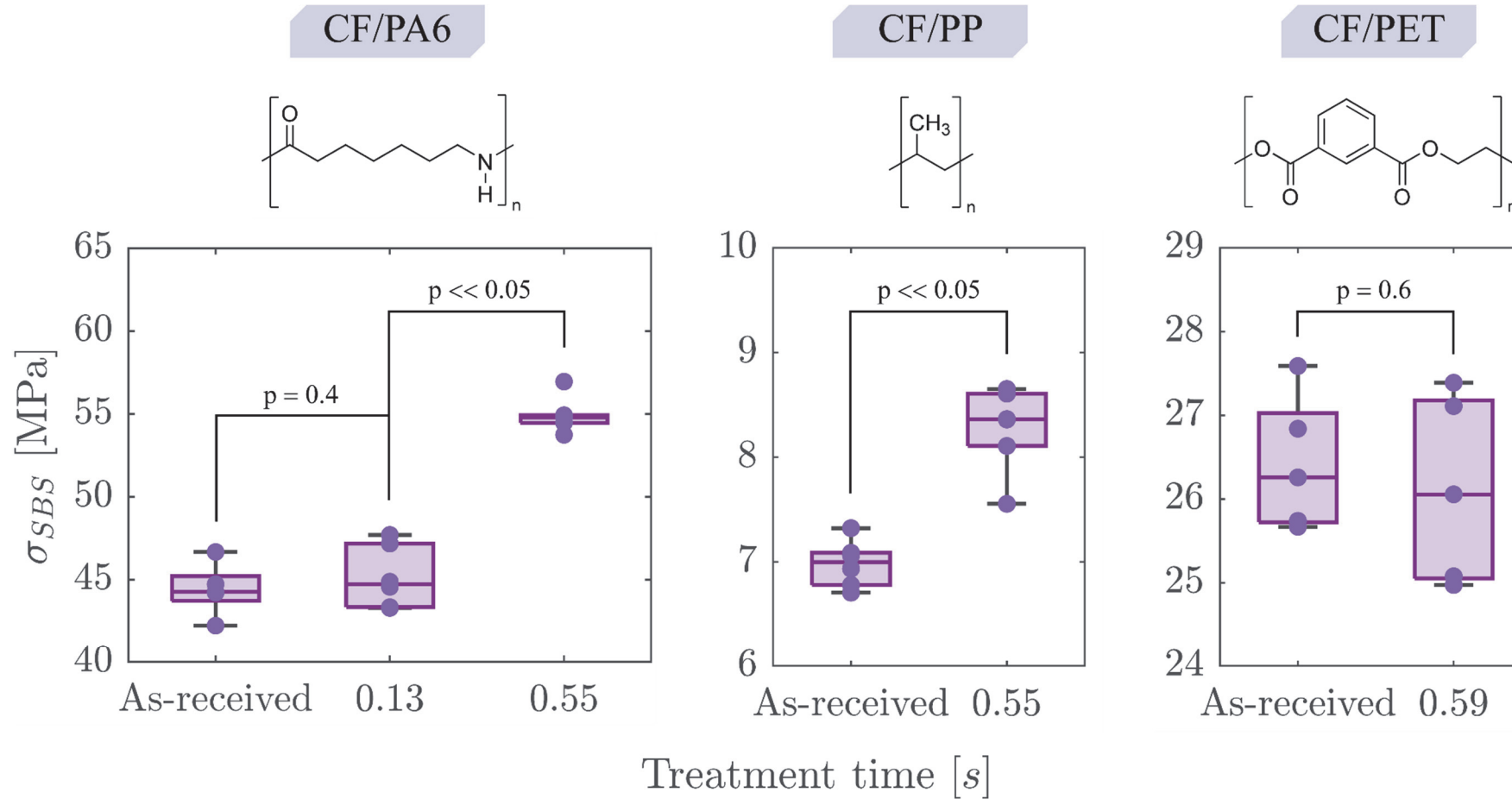
b Width

h Thickness

Failure mode



Short beam strength - results



Method benefits

1. High-speed treatment with affordable equipment
2. Improved SBS for CF/PA6 and CF/PP

Unresolved problems

1. Non-uniformly roughened fibre-surface
2. Negligible effect on CF-polyester interfacial strength



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021-066-2980

ACKNOWLEDGMENTS

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