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WHITE PAPER · MEMBRANE COATINGS

PFAS-FREE WATER REPELLENCY FOR NANOFIBER MEMBRANES

A 25 nm PlasmaGuard® S coating combined with plasma nanotexturing in a single roll-to-roll vacuum process step

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25 nm	127°	145°	1 step
PlasmaGuard® S, halogen-free, conformal	WCA on a membrane that absorbs water untreated	WCA on a hydrophobic membrane, from 109°	nanotexturing and coating, roll-to-roll, solvent-free

ABSTRACT

PTFE membranes owe their water and oil repellency to fluorine, and PTFE falls within the proposed universal EU restriction of PFAS. Non-fluorinated membrane polymers need a surface treatment to reach comparable repellency without closing pores. We describe a low-pressure roll-to-roll process that combines plasma nanotexturing of the fibre surface with a 25 nm halogen-free PlasmaGuard® S plasma polymer in a single process step, applied to two PFAS-free nanofiber membranes. On an intrinsically hydrophilic membrane that fully absorbs water, the coating alone gives an average water contact angle (WCA) of 109°, and nanotexturing plus coating 127°. On a hydrophobic membrane (109°), the values are 131° and 145°. Roughness, not only chemistry, sets the upper range, which makes WCA tunable to the application. Breathability, water-entry pressure, oil repellency and durability remain to be qualified per membrane.

Keywords: PFAS-free · nanofiber membrane · low-pressure plasma · PECVD · nanotexturing · hydrophobic · water contact angle · roll-to-roll

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1 INTRODUCTION: REPLACING PTFE

Expanded PTFE (ePTFE) has long been the reference material for venting, filtration and breathable membranes. It is intrinsically hydrophobic and oleophobic and needs no surface finish. PTFE is also a fluoropolymer, within the scope of the proposed universal restriction of PFAS under REACH: ECHA's Committee for Risk Assessment adopted its final opinion on 2 March 2026, and the Committee for Socio-economic Analysis is expected to adopt its final opinion by the end of 2026 [1].

Membrane makers are therefore moving to **non-fluorinated polymers**. These do not reach PTFE's repellency on their own, and many are intrinsically hydrophilic. A PFAS-free membrane needs a surface treatment that adds water repellency without closing pores or adding weight, and that runs on roll stock. Electrospun nanofiber membranes are the most demanding case: fibres of a few hundred nanometres, low basis weight, and limited tolerance to heat, solvents and web tension [2].

2 CHEMISTRY AND ROUGHNESS IN ONE PASS

Water repellency depends on two levers: surface chemistry and roughness. On a flat surface, a non-fluorinated low-energy coating reaches water contact angles of roughly 105–110°. Roughness amplifies this intrinsic behaviour. In the Wenzel regime the apparent angle follows $\cos\theta^* = r\cos\theta$, where r is the ratio of true to projected area [3]; when air remains trapped beneath the drop (Cassie–Baxter regime), apparent angles above 150° become possible [4] (Figure 2).

Europlasma combines both levers in its low-pressure roll-to-roll process (Figure 1). **Plasma nanotexturing** etches nanoscale roughness into the fibre surface; **PlasmaGuard® S**, a halogen-free plasma polymer from Europlasma's patented PFAS-free PlasmaGuard® platform, is then deposited at 25 nm [5, 6]. The two treatments are integrated into a single process step, with no solvent and low precursor consumption.

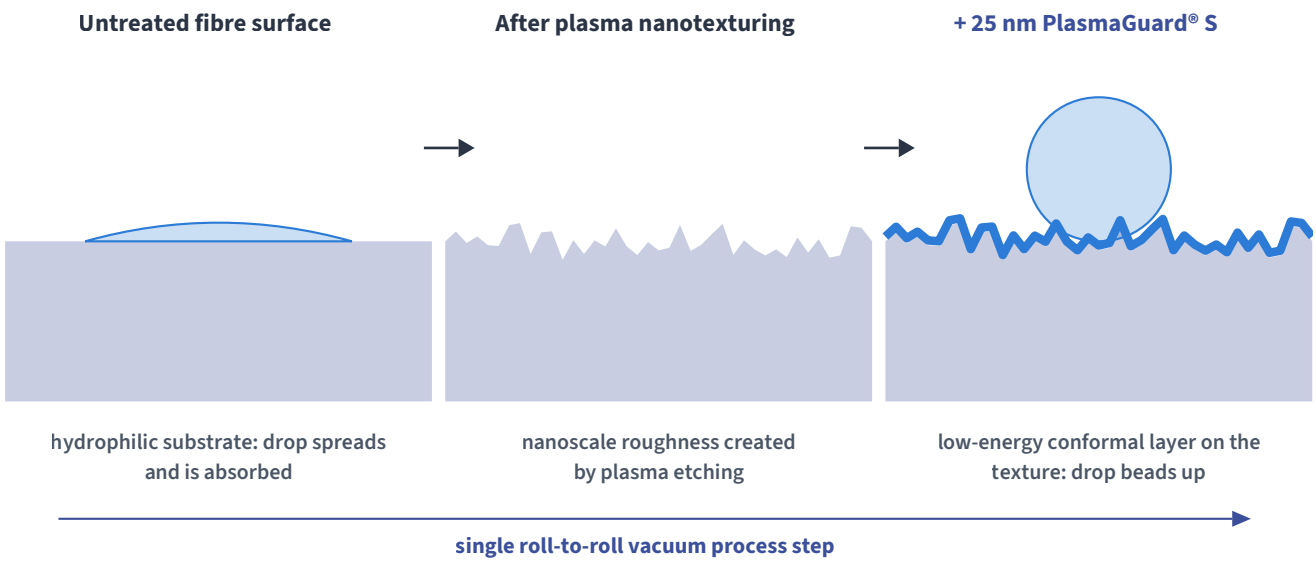


Figure 1. Concept of the one-step treatment: plasma nanotexturing of the fibre surface, then a 25 nm PlasmaGuard® S layer. Not to scale.

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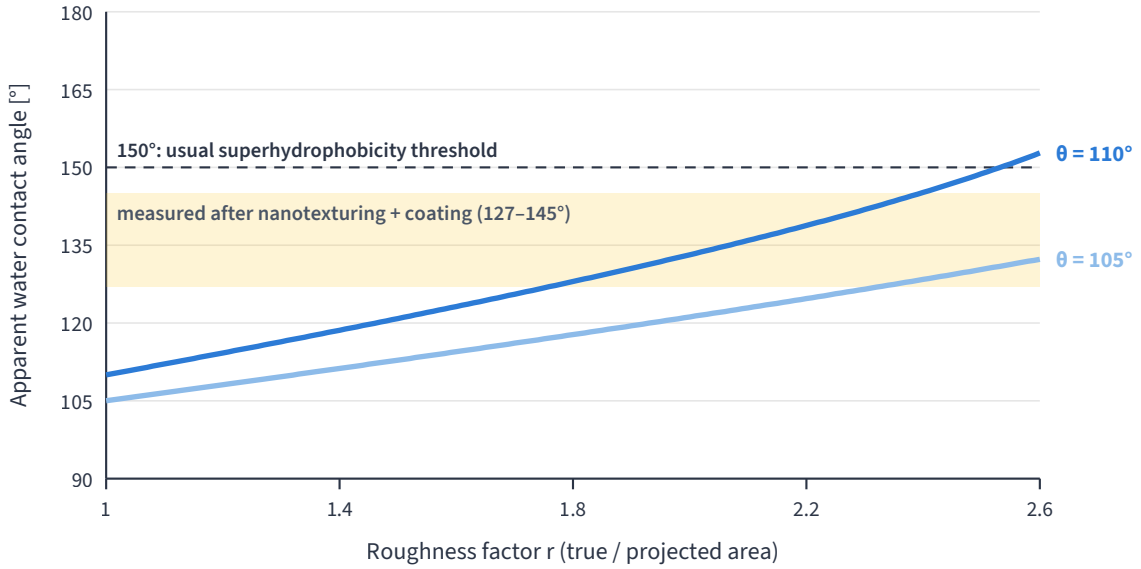
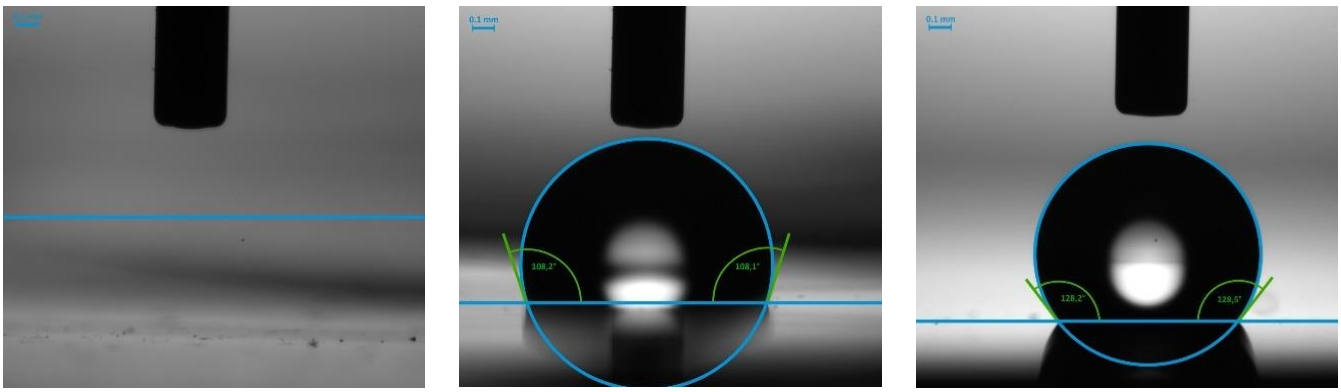


Figure 2. Wenzel model: apparent water contact angle versus roughness factor for intrinsic angles of 105° and 110°. Illustrative; the shaded band shows the range measured in Sections 3 and 4 [3, 4].

At 25 nm the coating is thin compared with fibre diameter and pore size, so the open structure of the membrane is expected to be preserved. Air permeability and water-entry pressure confirm this for each membrane (Section 6).

3 HYDROPHILIC NANOFIBER MEMBRANE

The first substrate is an intrinsically hydrophilic PFAS-free nanofiber membrane. Untreated, it absorbs a water drop completely and no contact angle can be measured (Figure 3a). After 25 nm PlasmaGuard® S, it becomes hydrophobic, with an average WCA of 109° (Figure 3b). With plasma nanotexturing before coating, the average rises to 127° (Figure 3c).



(a) Untreated: drop absorbed

(b) PlasmaGuard® S 25 nm

(c) Nanotexturing + PlasmaGuard® S 25 nm

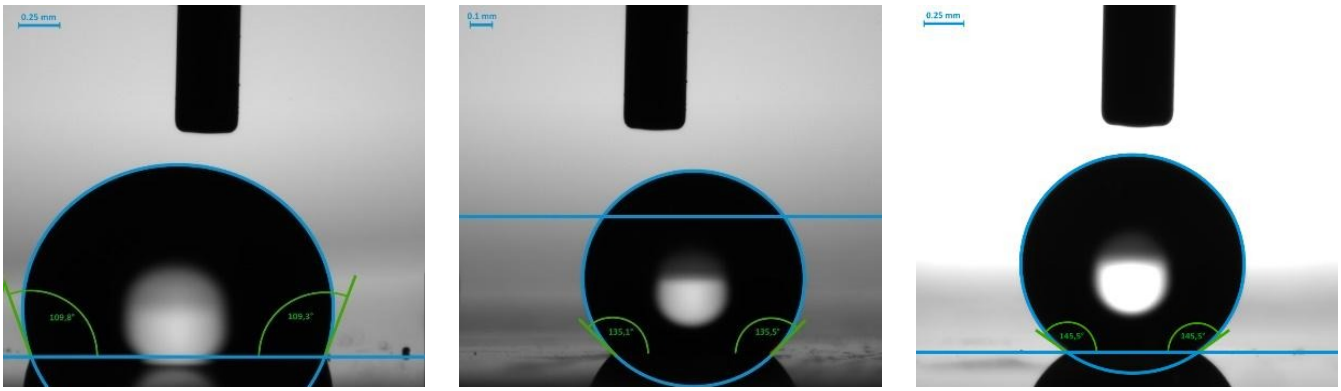
Figure 3. Water drops on the hydrophilic PFAS-free nanofiber membrane. Data: [6].

The coating alone turns a fully wetting membrane into a hydrophobic one; nanotexturing adds a further 18°.

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4 HYDROPHOBIC NANOFIBER MEMBRANE

The second substrate is a PFAS-free nanofiber membrane that is already hydrophobic, with an average WCA of 109° (Figure 4a). PlasmaGuard® S raises the average to 131° (Figure 4b), and nanotexturing plus coating to 145° (Figure 4c), within 5° of the threshold commonly used for superhydrophobicity.



(a) Untreated membrane

(b) PlasmaGuard® S 25 nm

(c) Nanotexturing + PlasmaGuard® S 25 nm

Figure 4. Water drops on the hydrophobic PFAS-free nanofiber membrane. Single images; Table 1 gives average values. Data: [6].

Table 1. Average water contact angle of two PFAS-free nanofiber membranes. Data: [6].

Membrane	Nanotexturing	Coating	Average WCA [°]
Hydrophilic nanofiber	No	Untreated	absorbed
	No	PlasmaGuard® S 25 nm	109
	Yes	PlasmaGuard® S 25 nm	127
Hydrophobic nanofiber	No	Untreated	109
	No	PlasmaGuard® S 25 nm	131
	Yes	PlasmaGuard® S 25 nm	145

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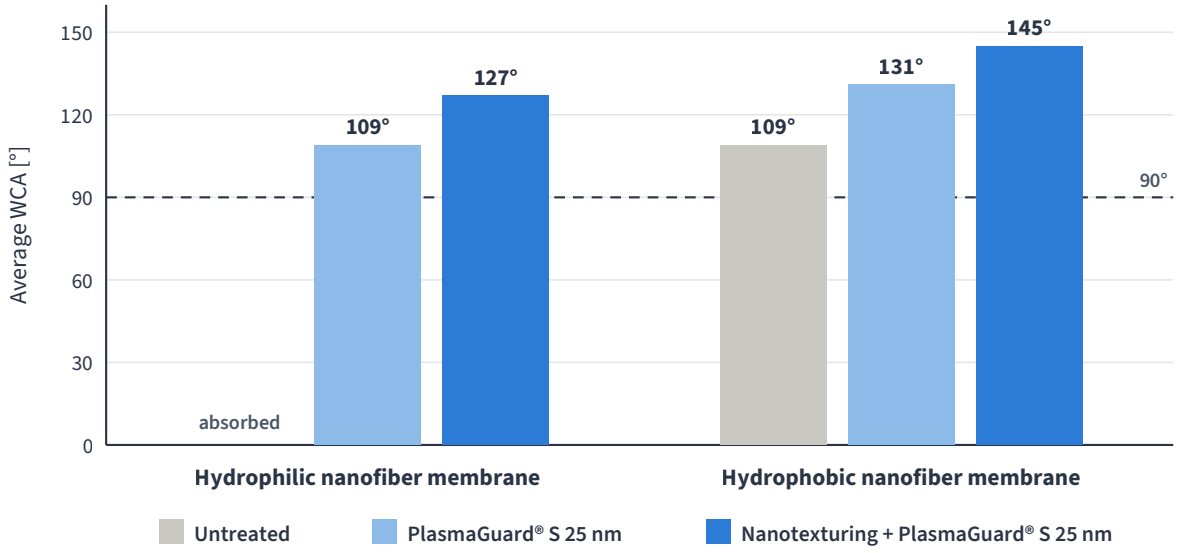


Figure 5. Average water contact angle of both membranes for each treatment. Data: [6].

Two observations follow (Table 1, Figure 5). The coating gain depends on the substrate: from complete wetting to 109° on the hydrophilic membrane, +22° on the hydrophobic one. Nanotexturing adds 14–18° on both, which shows that roughness, not only chemistry, sets the upper range. Combining or omitting the texturing step therefore makes the WCA tunable to the customer's target.

5 APPLICATIONS AND QUALIFICATION

The treatment is aimed at membranes that must block liquid water while letting air, vapour or sound through, and that are moving away from PTFE (Table 2). Every application is qualified on the customer's own membrane and pass criteria, on industrial-scale equipment, before any capital investment.

Table 2. Principal applications of the one-step PFAS-free treatment.

Segment	Problem to solve	Europlasma contribution
Medical membranes	Liquid barrier while venting air; PFAS-free devices; sterilisation	Halogen-free hydrophobic layer of 25 nm; tunable WCA; biocompatibility and sterilisation to qualify
Acoustic membranes: electronics, wearables	Water ingress protection with minimal acoustic loss; PTFE replacement	Ultra-thin conformal layer that adds negligible mass; nanotexturing for higher repellency
Air filtration: HEPA media, masks	Efficiency in humid conditions; fluorinated finishes being phased out	Hydrophobic treatment through the media in one dry roll-to-roll step

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6 VALIDATED SCOPE

Table 3. Status of claims for the one-step PFAS-free treatment.

DEMONSTRATED	QUALIFIED PER APPLICATION	OUTSIDE THIS STUDY
▪ 25 nm PlasmaGuard® S turns a water-absorbing nanofiber membrane hydrophobic (109°)	▪ Air permeability, pressure drop, acoustic transmission	▪ Oil repellency (oleophobicity): not measured here
▪ Nanotexturing + coating in one step: 127° and 145°	▪ Water-entry pressure (hydrostatic resistance)	▪ Roll-off angle: needed to claim superhydrophobicity in the strict sense
▪ Same treatment on hydrophilic and hydrophobic PFAS-free membranes	▪ Durability: ageing, sterilisation, abrasion, flexing	▪ Process conditions and line speed for a given membrane
▪ Low-pressure roll-to-roll process, solvent-free, halogen-free	▪ Biocompatibility for medical use	

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7 CONCLUSIONS AND WORKING WITH EUROPLASMA

A 25 nm halogen-free plasma polymer makes PFAS-free nanofiber membranes hydrophobic, including one that fully absorbs water. Adding plasma nanotexturing in the same roll-to-roll process step raises the water contact angle to 127° and 145°, close to superhydrophobicity, without fluorinated chemistry and without solvent. The approach targets medical, acoustic and air-filtration membranes that are replacing PTFE.

Europlasma is the Plasmalex Group's competence centre for low-pressure plasma, with more than 30 years of PECVD process, chemistry and equipment development. Trials run on the customer's membrane in Europlasma's roll-to-roll vacuum units (Figure 6); supply follows by toll coating or by a turnkey system with qualified process chemistry. A companion white paper reviews nanomembrane applications and the surface functions they require [7].



Figure 6. Europlasma low-pressure roll-to-roll plasma system, chamber open.

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TEST METHODS

Table 4. Summary of test methods.

Property	Method
Water contact angle	Sessile drop, water, 20 °C, optical drop-shape analysis; average values reported [6]
Coating	PlasmaGuard® S, low-pressure PECVD, 25 nm nominal thickness
Nanotexturing	Low-pressure plasma etching, integrated with coating in one roll-to-roll process step
Substrates	Two PFAS-free nanofiber membranes, one intrinsically hydrophilic, one hydrophobic

All results obtained on Europlasma low-pressure plasma equipment. PlasmaGuard® is a trademark of Europlasma.

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