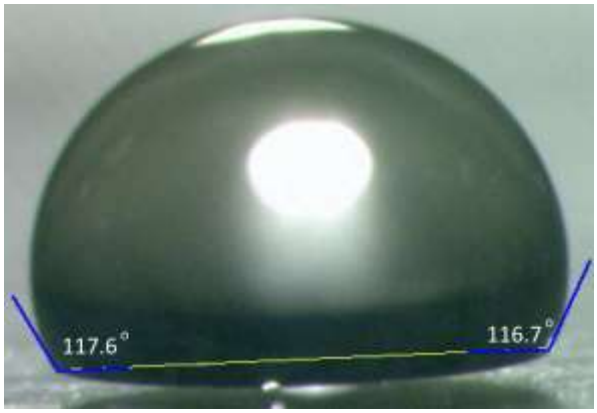
CYTONIX

FluoroPel, an oleophobic acoustically transparent vent and membrane coating

FluoroPel is a fluorocarbon polymer carried in either fluoro-solvents or MEK. FluoroPel dries to a thin, transparent film with excellent hydrophobic and oleophobic properties. It repels oils, water, silicones, paints, photoresists and organic solvents when cured. FluoroPel can be used to improve corrosion resistance and utilized at temperatures up to 200°C for its anti-wetting, anti-stiction and anti-migration properties. Applications for FluoroPel include coating membranes, laboratory vessels, microfluidic devices, printed circuit boards, ball-grit arrays, MR heads, micro-motors, MEMS, and hard disk drive components. Fabrics, filters, mesh and membranes coated with FluoroPel retain air and sound permeability. An oleophobicity grade of up to 8 on PTFE membranes can be achieved. FluoroPel is provided as either a 100% solids resin, 20% concentrate or pre- diluted low viscosity, low surface tension solution usually at 2% solids in a fluoro-solvent or MEK. FluoroPel is usually used at concentrations of 0.2% to 4% solids. FluoroPel is easy to apply by dipping, spraying or by syringe-dispensing and it air-dries quickly.



Materials and Methods

Material used for this study include PTFE membranes, metal dishes, microscope glass slides and plastic slides. Stock FluoroPel was synthesized at Cytonix utilizing proprietary production methods and diluted to 2% with AE3000. Oleophobicity grade was assessed using the AATCC Spec 118-1992 guidelines.

Films of FluoroPel-2% were made in metal boats and on glass slides and cured at 100°C for 60 minutes. After cooling, a 50 µl drop of gasoline, ethanol, acetone, IPA or auto oil was placed on the films for 60 seconds and blotted off. Microscopy was used to examine the films and compared to untreated control. Contact angles to water were measured by placing a 2 µl drop on the films and contact angles calculated using ImageJ and a plugin for drop analyses. Contact angles to mineral oil were also measured by placing 2 µl drops on the films. This series was used to assess the robustness of FluoroPel before and after exposure to gasoline, ethanol, acetone, IPA and auto oil.

Films of FluoroPel-2% were also made on PTFE-membranes and plastic slides. Films were made by dipping the substrates in a 2% solution of FluoroPel. The dip-coated substrates were dried at 60°C for 60 seconds and aged for over three weeks at room temperature to cure the FluoroPel.

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Table 1. Properties of FluoroPel Solution

Property	
Product Codes	PFC600A, PFC800F, PFC400UC
Color	Colorless or yellow liquid
Clarity	Lightly turbid to Clear
Concentration	0.2-100%; 2% recommended for membranes
Odor	Light ether-like (or acetone)
Flammability	600/800 non-flammable, 400-series flammable
Viscosity	>0.41 cP depending on polymer concentration
Solubility	PFC800, AE3000, HFE7200, Vertrel-MCA
Shelf Life	>5 years for PFC800/600. 6 months for PFC400
One Part System	Yes
Application Options	Dipping, spraying, brushing, syringe-dispensing

Table 2. Properties of FluoroPel films

Property	
Appearance	Clear, odorless and colorless film
Chemistry	Fluoro-Carbon C6
Contact Angle to Water	~115°
Contact Angle to Oil	>55°
Surface Tension	8-12 dynes/cm
Oleophobicity grade	>8
Hardness	>2B pencil
Flammability	Non-burning
Tracer	UV tracer for quality control (at request)
Heat stability continuous	150°C
Max heat stability one hour	250°C
Refractive index Surface	~1.34
Toxicity	HMIS Rating Health = 1
Ease of Application	Excellent
Solvent/Chemical Resistance	Excellent after curing
Transparent	Yes
Electric conductivity	Yes (at <0.5 µm film thickness)
Ease of Dry	Dries at room temperature in <5 minutes

Table 3. FluoroPel film thickness

Property	
Film thickness at 0.2% polymer	~0.05 µm
Film thickness at 2% polymer	~0.1 µm
Film thickness at 5% polymer	~0.5 µm
Film thickness at 10% polymer	~1.0 µm
Film thickness at 20% polymer	~2.0 µm

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Table 4. Electrical properties of FluoroPel films

Coating Thickness	Surface Resistance (Ω)	Volume Resistance (Ωm)
0.05 µm film	Conductive	Conductive
0.1 µm film	Conductive	4×10^{20}
0.5 µm film	1×10^{9}	8×10^{20}
1.0 µm film	5×10^{11}	ND
2.0 µm film	2×10^{14}	ND
>100 µm film	2×10^{17}	ND

*Electrical properties determined on aluminum plates. Measures presented are approximate.

Table 5. Water contact angles of 0.5 µm FluoroPel films

	Water Contact Angle*
Air dried for 1 hour	114.2° (Range: 113.1°-115.4°)
Baked at 90°C for 15 minutes	119.3° (Range: 116.7°-121.6°)

* Numbers shown are an average of over 4 readings.

Table 6. Solvent and UV-light resistance properties of 0.5 µm FluoroPel films

Exposure (2 minutes)	Water Contact Angle*
Toluene	112.7°
Acetone	104.8°
De-icing fluid	100.6°
FC-40	117.3°
Perfluoropolyether vacuum oil	Removes coating
UV light – 10 minutes	88.2°
UV light – 20 minutes	71.9°

* Numbers shown are an average of two readings.

Table 7. Heptane contact angles of 0.5 µm FluoroPel films

	Average Heptane Contact Angle*
Air dried for 4-5 hours	26.6° (Range: 23.7°-29.5°)

* Numbers shown are an average of over 4 readings.

Table 8. Microscopy evaluation of FluoroPel films after chemical exposures

	Untreated	Acetone	Ethanol	IPA	Gasoline	Auto-Oil
Glass - 180°C cure	Robust	No Change	No Change	No Change	No Change	No Change
Metal - 180°C cure*	Robust	No Change	No Change	No Change	No Change	No Change
Plastic - 110°C cure	Robust	No Change	Circular Ghost	No Change	No Change	No Change

* Metal boats were evaluated using stereo microscopy

Table 9. Water contact angles for FluoroPel films after exposures

	Untreated	Acetone	Ethanol	IPA	Gasoline	Auto-Oil
Glass - 180°C	>110°	>110°	>110°	>110°	>110°	>110°
Plastic - 110°C	>110°	>110°	>110°	>110°	>110°	>110°
Membranes - 110°C	>110°	>110°	>95°	>110°	>110°	>110°

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Table 10. Mineral oil contact angles for FluoroPel films after exposures

	Untreated	Acetone	Ethanol	IPA	Gasoline	Auto-Oil
Glass - 180 °C	>50°	>50°	>50°	>50°	>50°	>50°
Plastic - 110 °C	>50°	>50°	>50°	>50°	>50°	>50°
Membranes - 110 °C	>100°	>100°	>95°	>100°	>100°	>100°

Table 11. Dodecane oleophobicity of PTFE membranes after exposures

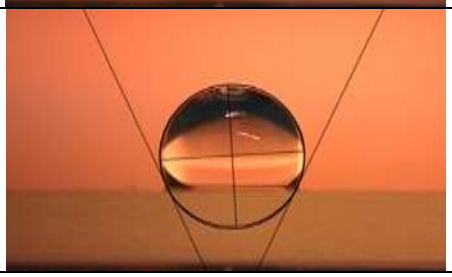
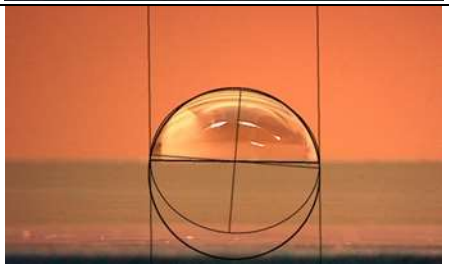
	Untreated	Acetone	Ethanol	IPA	Gasoline	Auto-Oil
Membranes - 110 °C	Pass	Pass	Pass	Pass	Pass	Pass

The FluoroPel films were not adversely affected by acetone, IPA, gasoline or auto-oil. The ethanol exposed region on plastic slides (cured at 110°C) showed a circular ghost after the drop of ethanol was removed. However, after the ethanol completely evaporated the film surface appeared intact. This suggests that the coating was inadequately cured or that ethanol partially dissolved the FluoroPel coating. FluoroPel appears to be a robust coating with good chemical resistance.

Table 12. FluoroPel films and long-term performance

FluoroPel Coating Date	June 2, 2005
Initial Contact Angle	>110°
Initial Film Quality	Good
Contact angle on Oct 2014	>110°
Film Quality on Oct 2014	Good no-change

Table 13. Contact angle analyses of FluoroPel on glass

Water	Mineral Oil
	
	
2.0% polymer on glass Water Contact angle: >110°	2.0% polymer on glass Oil Contact Angle: >80°

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