

Going Green With High Performance Nano-Coatings for Glass

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Abstract

Recyclability, environmentally friendly chemistries, and spectrally selective control of energy transmission while maintaining clear vision makes glass the ultimate substrate for green technologies. Thin film nano-coatings enhance the performance and quality of glass substrates giving more functionality and aesthetic value. Improved light transmission can reduce energy costs and increase solar cell efficiencies. Protection can also be provided against the relentless environmental stresses of pollution, corrosion, and mechanical scratching. These functional coatings on glass will be reviewed along with their added value as they become essential to the performance of engineered constructions such as buildings, automobiles, containers, solar cells, and multi-touch panels.

Introduction

Most glass products would not have the properties that make them so useful without coatings. 550 MM ft² of flat glass is coated annually in North America by either the manufacturer or an end user. 95% of all glass containers manufactured in US (36 BB/yr) and 75% Worldwide (180 BB) are produced with one or more coatings. Application of coatings are an essential part of glass manufacturing. Opportunities exist for improved Functionality and improved Processes.

The evolution of engineered surfaces through Coating design is what makes the difference for mainstream and custom added value solutions in modern glass constructions. The recent scientific discoveries of new materials at a nano scale and rising environmental and convenience standards are driving the glass industry in an emerging field of "functional design". Common applications include spectrally selective Low-Emissivity solar control, Anti-Reflection stacks, "Easy-Clean" glass and Transparent Conductive Oxides for smart windows and displays.

Large Area Thin Film CVD and PVD Methods

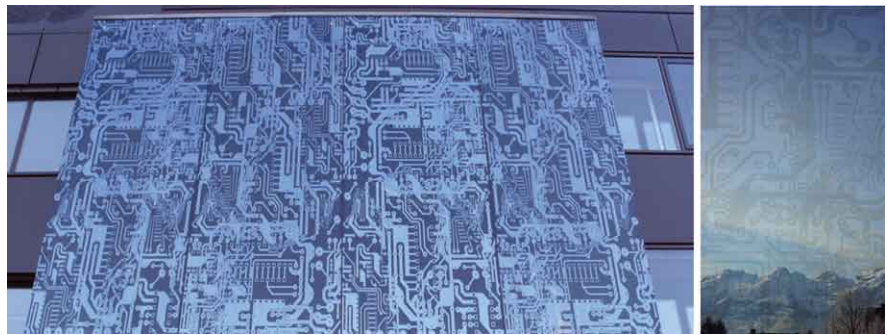


Figure 1.

Photo of LustReflex coating on spandrel glass, courtesy Steindl, Austria

On-Line: pyrolytic Chemical Vapor Deposition processes deposit semi-conductive metal oxides directly during the float glass production while the glass is still hot in the annealinglehr. Higher density hard coatings are obtained at high production rates, however, yields and spectral performance are lower and chemical by products can be more harmful to the environment.

Off-Line: sputter Physical Vapor Deposition magnetron processes deposit one or more coats of metal oxide under a vacuum to finished glass. PVD coatings are better reflectors of UV and IR wavelengths of light, however these coatings are not as hard and dense.

Capital costs¹ for these application methods require large area scales of economy .

Capital Costs	
Pyrolytic process line	~ \$5MM / MMsqm/ year installed
Sputter process line	~ \$25MM /MMsqm/ year installed

Nevertheless both technologies remain as supplemental high energy processes (see table below) and even though glass is a durable long life material that can save energy in an installation, industries are beginning to consider complete carbon footprints.

Sputter coatings:	20-100 KW/sqm (DC) 200°C substrate Temp. (further annealing ?)
Pyrolytic coatings	50 – 100 KW/sqm, speed 3-10 m/min.

Other important factors of these large area coatings are inherently limited design space (not easily patternable) and sensitivity to intrinsic stresses due to the nature of deposition. Molecules could cause damage of the surface structures at the atomic scale due to a bombardment by high-energy particles². Scratch resistance, glass corrosion, or a complete coating disintegration in the field may be the consequence and so often do not allow Side One applications.

Deposition of Thin Films from Solutions

Chemical silvering of glass from wet film deposition processes is one of the oldest processes and still in use today. Other large area industrial thin film solution processes involve sol-gel immersion or dip coating methods of suitable metal organic compounds to form optical coatings. The type of bonding and adhesion that occurs can be strongly influenced by thermal energy to drive chemical reactions and formation of interfacial layers³.

Fused, diffused, or sinter-bonded coatings (Temper coatings): Printable functional nano-coatings for glass have been developed⁴. Advantages include easy patterning to allow for new designs, functionalities, and ease of integration into standard glass thermal treatments such as annealing, heat strengthening, or tempering. Layer thicknesses can range from 10-1000 nanometers

LustReflex – silver or gold reflection also in combination with glass colors

- Functional performance is a semi-transparent, semi-mirror coating
- Easy screen and digital printing
- Applications are appliance glasses (refrigerator, oven, shower, furniture)
- Architectural glasses (Side One) with EN1092-2 compliance

Surface structures (AFM) are from nano-smooth (low friction) to nano-rough

Anti-Reflection (single layer) coatings

- Functional performance: reduced one side reflectivity Refl.Vis <1,5%
- Easy printing (screen-printable)
- Applications are solar panel and display glass covers
- IEC61215, EN1092-2 compliance

Such spectrally selective, screen printable thin-film coatings can enhance the performance and quality of glass substrates used for the cover glass in photovoltaic (PV) cells while reducing costs compared to other AR coating methods. Their anti-reflective properties increase light transmission by up to 4% at various wavelengths through the glass to the PV substrate with associated improvements in net solar gain and cell efficiency.

UV Functional Transparent coatings

- Functional performance Blocks 50 to 90% of UV transmission by reflecting or absorbing UV
- Easy patternable by screen- or digital printing
- Applications UV protection, Bird Collision coatings

Transparent conductive coatings

- Functional performance are sheet-resistance < 600 Ω/ , < 200 Ω/ (Van Der Paw method) under reduced conditions, Transm.Vis>80%
- Easy patternable by screen- or digital printing
- Applications are display glass, electronic glass, security glass for buildings.

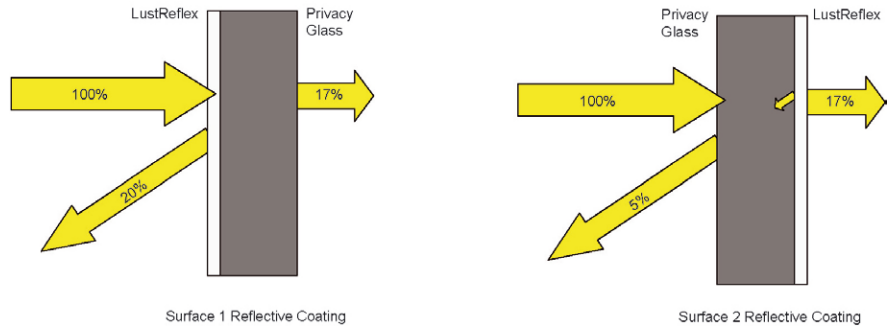


Figure 2.

Percent Reflection of LustReflex Reflective Coating on Dark Privacy Glass



Figure 3

AFM picture of a LustReflex coating

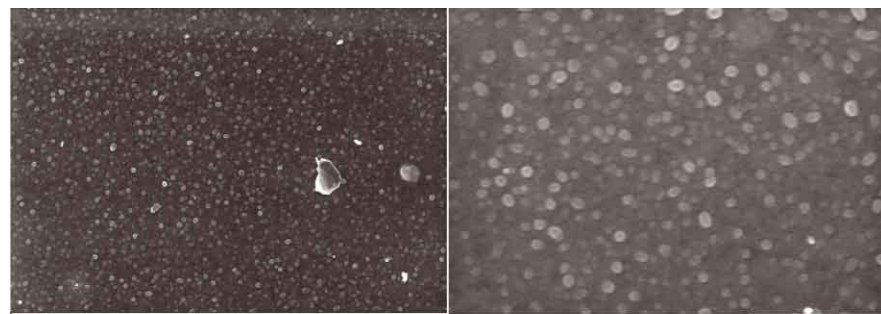
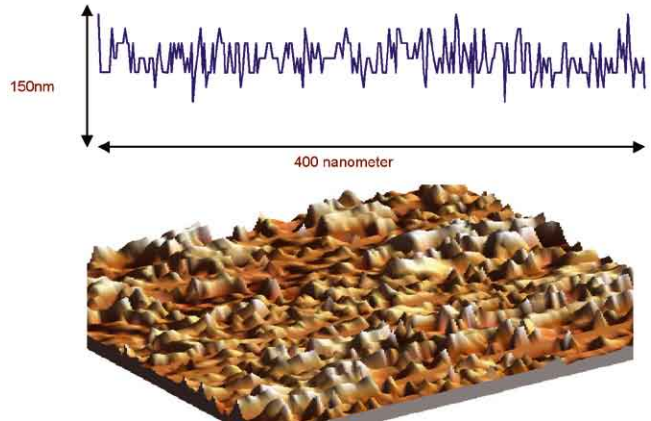


Figure 4.
High Resolution SEM of Reflective LustReflex Coating

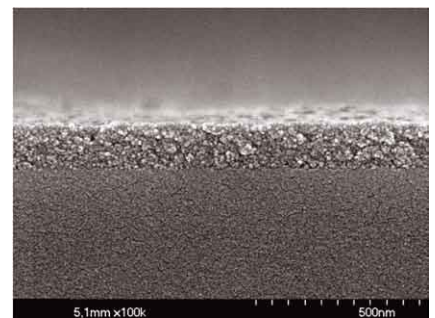


Figure 5
High Resolution SEM Anti-Reflection Glass Coating Structure

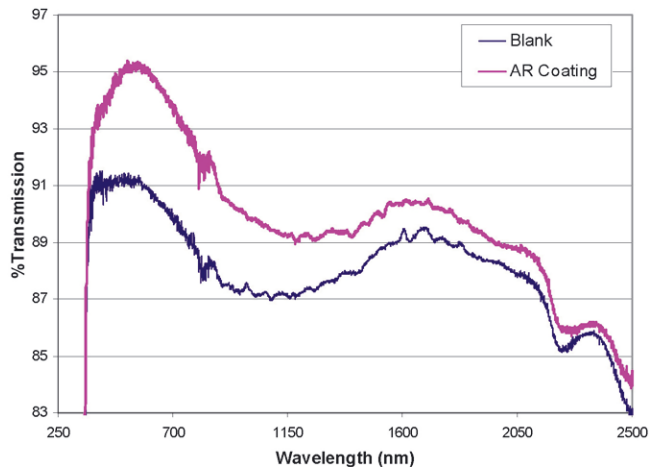


Figure 6
Spectrally Selective Light Transmission increase with an AR Coating Screen Printed on One Surface of a Soda-Lime Glass Substrate

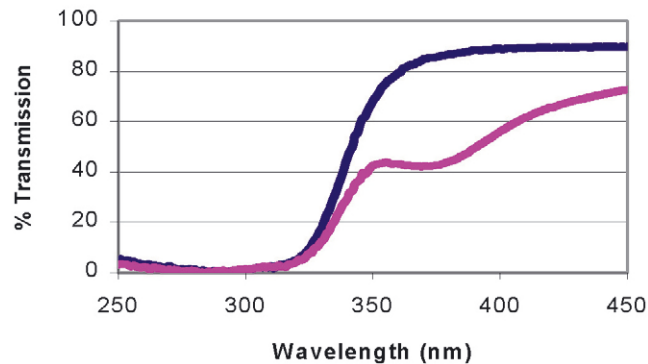


Figure 7
UV Reflecting Coating 348-101 Screen Printed on a Soda-Lime Glass Substrate

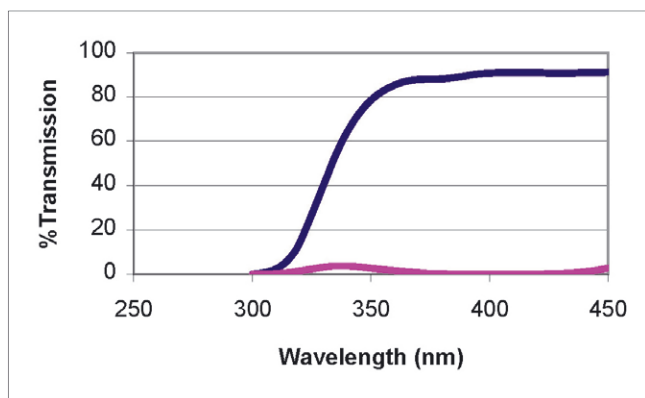


Figure 8
UV Absorbing Coating 348-149a Screen Printed on a Soda-Lime Glass Substrate

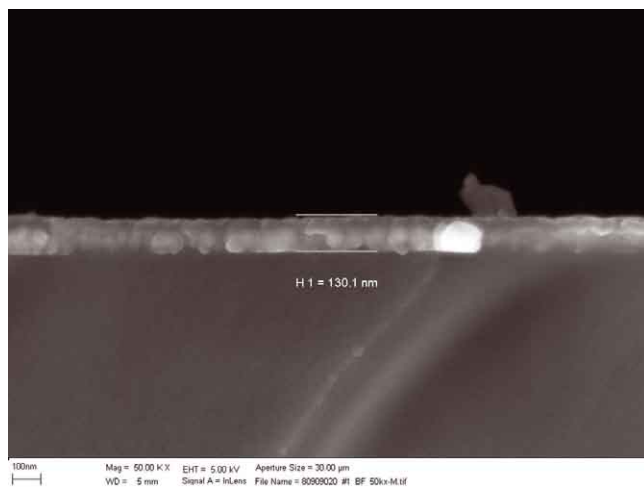


Figure 9
FESEM cross section of a screen printed TCO coating on tempered glass

Diffusion colors coatings

- Functional performance (100% UV block), Cd- free red coloration
- Depth of Copper Diffusion 2 – 4 µm, 1.0 g Cu /m²
- Easy printing (screen-, or roller printable)
- Applications are furniture, architectural, container glasses
- EN1092-2 compliance

Self-assembling covalently bonded Nanofilm™ (LT cure coatings): Room temperature hydrolysis and condensation reactions utilize nanotechnology to deliver site specific performance attributes. Self assembling molecules bond covalently and form nano scale films that can enhance chemical and mechanical performance. Silane chemistry is typically utilized and customer specific applications require different functional groups, activation promoters and suitable solvent/carriers. A typical hydrolysis and condensation reaction is illustrated in figure 11.

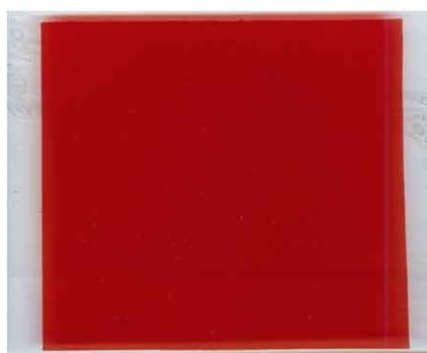


Figure 10.
Red Shade Cd Free Diffusion Color 6 mm Float Glass Heated 690°C for 5 min.

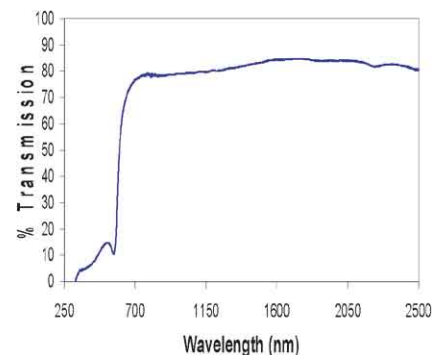
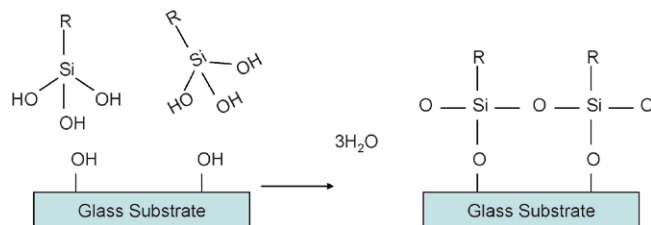


Figure 11.
Self Assembling Hydrolysis Condensation Reaction



Molecules settle on the glass substrate surface and covalently bond while self-assembling into a continuous thin film less than 500 nm. Durable film forming compositions⁵ can be formed from amphiphilic molecules consisting essentially of $RmSiXn$ where R is an apolar or fluorinated alkyl group of about 10 - 30 carbon atoms, m plus n equals 4, and X is selected from the group consisting of halogens, hydroxyl, and alkoxy groups.

Invisible and optically clear films with visible light transmission of >98% can be achieved. The amphiphilic chemistry of the R molecule lowers surface energy and can repel water and oils creating hydrophobic and oleophobic functionality making glass surfaces harder to soil, easier to clean, stain resistant, and chemical resistant. Mechanical properties include mar resistance and enhanced micro-scratch resistance. Continuous long exposures to elevated temperatures, UV, chemicals, and mechanical action will eventually erode these molecular layers. However these coatings are easy to apply with rapid room temperature curing and can be easily refurbished as needed in the field.

Ultraseal™

- Top coat for ophthalmic lenses, lab ware, dinner ware.
- Architecture ESG,VSG,IGU, technical glass (display), stain and graffiti resistant.

Float soda-lime glass panels coated with Clarity UltraSeal™ AB show significant reductions in static and dynamic coefficients of friction⁶. Test Procedure : ASTM D1894

Speed 150mm/min, 200gm sled, 2.5 in2 (16.1cm2).

Soda Lime Glass	Static COF	Dynamic COF
Uncoated glass (control)	0.34	0.28
UltraSeal AB coated	0.19	0.17
UltraSeal AB5 coated	0.13	0.12

Defender™

Applications include Automotive windshield, side lights. Repels rain to improve visibility. Increases driver vision 34% on a rainy night. A 34% increase can add about 1 second to a driver's response time. At 60mph, that's an extra 88 feet of pavement to brake, to turn, to be safe. Snow and ice are easier to remove and an easy-clean barrier to bugs and bird droppings is present. Durability in Automotive WS conditions of 6 months or more.

Coated glass specimens have been tested for chemical, temperature, UV exposures and have been demonstrated



Figure 12.
Permanent Marker Pen is Removed by Scotch Tape on Coated Glass⁶



Figure 13.
Treated and Un-treated Automotive Glass in a Rainstorm⁶

DIN 58196-2	Boiling water Test – 60 mins
DIN 50017 KK	High Humidity/High Temp : 144 hours at 95% RH/40 C
DIN 50021 SS Cass 24h	Salt Spray test, 20 cycles
DIN 58196-5	Abrasion Test , 50 cycles with cheesecloth
DIN 58196-6-K2	Tape adhesion test
UV Exposure	30 hour SUN test, 1.1 kw, 820 W/m2
Temperature cycling	- 400 C (2 hours) to 930 C (2hour) ; Five cycles
Chemical exposure	Acetone, Diesel, Ajax (window cleaner),Alcohol, Soft drink -10 mins

Table 1

to pass the following exposures⁶, see table 1.

Acid Rain Chemical resistance: Solution preparation of Ammonia, NaOH, KOH, and CaOH were added with addition of tap water to make a 1-liter solution. H₂SO₄, HNO₃, and HCl were added with addition of tap water to make a 1-liter solution. The anion solution was added to the cation solution. Concentrated solution of anions (Cl⁻, NO₃⁻, and HSO₄⁻) and cations (H⁺, NH₄⁺, K⁺, Na⁺, and Ca⁺⁺); pH = 1. Prior to testing, the mixture was thoroughly stirred to ensure all parts

were suspended. Coated substrates were immersed in Acid Rain solution for 30 minutes at 80°C, then rinsed and dried at 80°C for an additional 30 minutes. Water contact angle measured before and after acid rain test

Clarity Defender™ coated glass panels were subjected to an accelerated Salt solution test⁶. 2 Hours of immersion in a Boiling NaCl solution. Water Contact Angles measured before exposure, and after 1 hour and 2 hour exposures.

	Defender Coated	Uncoated
Before Test	97°	49°
After 1 hour immersion	98°	38°
After 2 hour immersion	94°	29°

EnergySlayer™

Designed to reduce energy loads by trapping IR radiation at the surface. Potential uses Laminated automotive glass, architectural glass, energy controlling window film treatments. Functional performance IR-absorptive TNIR <40%. Thin (< 25 microns), flexible coatings applied to glass or polymer film (PVB). High visibility coating with transmittance as high as 85%. Final coated glass can range in visible light transmittance from 55% to 70%. Fine tuning of absorption characteristics – either single layer or dual layer coating. Absorbs as much as 95% of IR radiation in 900 -2500 nm range and blocks > 95% of UV radiation.

Two layer hybrid coatings self-assembling sinter- and covalently bonded:

Lotus-effect™ Easy-clean coatings⁷

- Functional performance is super-hydrophobic easy-clean or fingerprint resistant coating
- Applications are enabling all weather camera housings and cover glass, Anti-fingerprint solutions on touch-screens, self-cleaning solar-cover glasses.

Conclusions

Finding the right coating solution also has to take into account secondary processing operations such as cutting, grinding, annealing, heat strengthening, and sealing to name a few. At the very end, the total cost of ownership could be much higher than projected and could significantly impact the total economic balance of a glass construction.

On the other hand value add glass confectioning facilities of tomorrow will have to dispose a whole range of complementary coating solutions to assemble them in a fast and cost effective manner on demand for a specific custom application. This is the reason why today we are successfully introducing a new range of user friendly performance nano-coatings

References

- [1] source ARKEMA, ICCG7 2008
- [2] M. Lottiaux, C. Boulesteix, G. Nihoul et al., Thin Solid Films 170Z1989.107
- [3] H.K. Pulker, Coatings on Glass, Elsevier, 1984, p. 64-275
- [4] M. Baumann, K. Fritsche, G. Sakoske, G. Tuenker, "Easy Printable Nano Coatings for Glass", Glass Processing Days, Finland 2005, p. 193-195.
- [5] B. Singh, R. Subramaniam, US Patent 5,078,791, Jan 7, 1992
- [6] NanoFilm Ltd, Valley View OH.
- [7] M. Baumann, G. Sakoske, L. Poth, G. Tuenker, "Learning From the Lotus Flower- Selfcleaning Coatings on Glass", Glass Processing Days, Finland 2003, p. 330-333.

QUV Accelerated Weatherometer Exposure Results

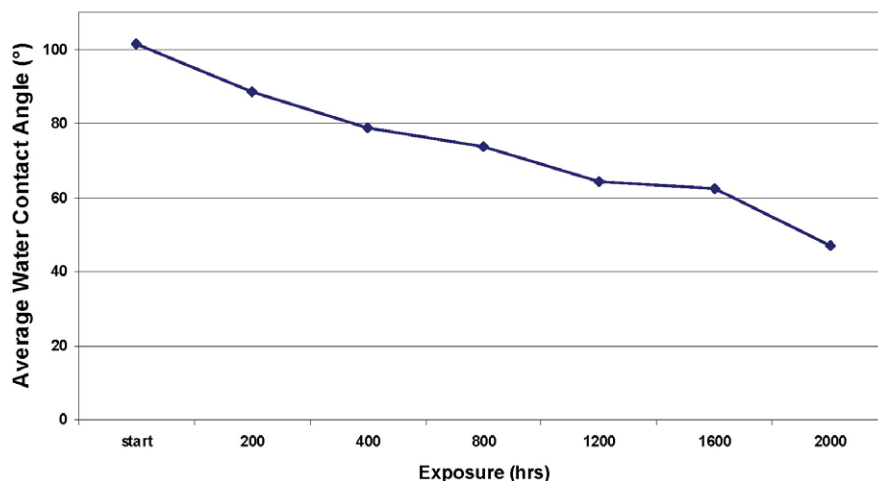


Figure 14.

QUV Accelerated Weatherometer Testing⁶

Figure 15.

Acid Rain Tests of Soda-Lime Glass Control and Treatment with NanoFilms

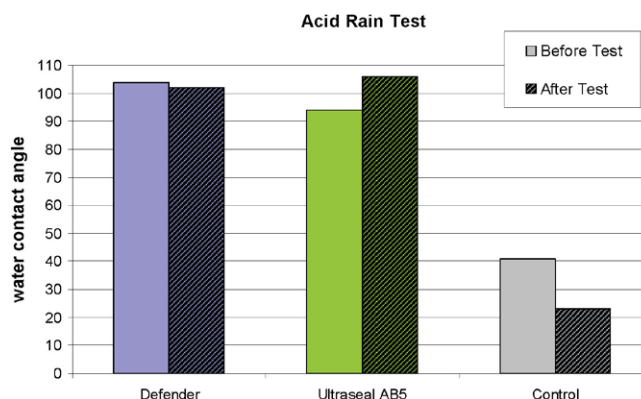
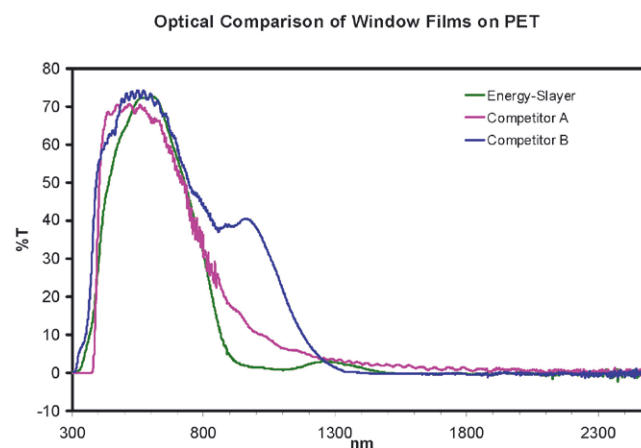


Figure 16.

IR Absorption Spectrally Selective Performance of NanoFilms on PET⁵



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高性能纳米涂层让玻璃更节能环保

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摘要

可回收、环保、透光、光谱选择性吸收和控制能量传递使玻璃成为终极节能环保产品。而功能性纳米涂层更是提升了玻璃的品质和审美价值：通过改善光的透射性能可以减少能量损耗；提高太阳能电池效率；减少环保压力；提高玻璃的耐侵蚀和耐机械划擦性能。功能性玻璃涂层因其高附加值已成为建筑、汽车、器皿、太阳能电池以及触控面板等工程和建筑材料不可或缺的产品。

介绍

大部分玻璃产品因为功能性涂层展现出优越性能而被广泛使用。北美每年有5.5亿平方英尺（5110万平方米）的平板玻璃被生产厂家或最终用户装饰涂层。美国生产的95%的玻璃容器（每年360亿只）和全球75%的玻璃容器（每年1800亿只）都装饰有一种或多种涂层。玻璃涂层装饰已成为玻璃生产和加工的必要步骤之一。改善玻璃涂层的功能和改进装饰工艺仍然存在发展空间。

采用涂层提高玻璃表面性能是现代玻璃深加工产品提高附加值的重要途径。近代科学发现的更加节能环保和使用方便的纳米新材料已将玻璃行业带进了一个新兴的功能性设计领域。常见的涂层有LOW-E膜，阳光控制膜、防反射膜、易清洗膜以及智能窗和显示器用的透明导电氧化物膜。

大面积CVD和PVD涂层方法

在线：高温分解化学气相沉积过程是在浮法玻璃生产过程中，在玻璃仍在退火炉的高温环境中，在玻璃表面沉积半导体金属氧化物。该膜的特点是坚固耐用和高密着性。但成品率低，光学性能

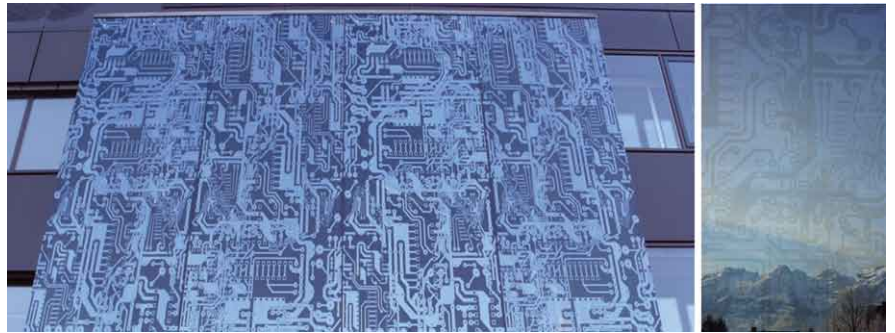


图1.

幕墙玻璃用的高反射涂层照片，courtesy Steindl, 奥地利

差，化学副产品对环境危害大。离线：物理气相沉积磁控溅射过程是在真空环境中，一层或多层金属氧化物沉积在成品玻璃上。PVD涂层对UV和IR光的反射性更好。但这种膜密着性和牢固度不够。

这些方法设备投资成本高

设备投资成本	
高温分解生产线：	5 百万美元 / 百万平方米/每年
溅射生产线	25 百万美元 / 百万平方米/每年

虽然玻璃是持久耐用产品，从这个意义说其安装使用后能节约能源，但是这两种镀膜方法都需要高能耗，目前行业内已经在考虑碳的排放问题。

溅射涂层：	20-100 KW/m ² (直流电) 200° C 玻璃基体温度 (再退火?)
高温分解涂层：	50 - 100 KW/m ² , 速度 3-10 m/min.

这些大面积涂层的其他不利因素：固有的设计局限性（很难设计图案），且沉积层对玻璃内在应力敏感。由于高能粒子的轰击，在微观状态下，沉积到玻璃上的分子会损害表面结构。这样会导致涂层的耐刮擦性能、耐腐蚀性能下降或整片膜的脱落，因此通常不允许这种镀膜玻璃膜面

朝外。

溶液沉积镀膜法

溶液沉积化学镀银是最古老的镀膜方法之一，而今仍在沿用。其他大面积工业镀膜方法包括溶液-凝胶浸镀法通过浸渍合适金属有机化合物来形成光学涂层方法。这种涂层易受热能影响而发生化学反应形成界面层。

熔融的扩散的或烧结的涂层（钢化涂层）：可印刷的功能性纳米玻璃涂层已经研制成功。优点是可以自由设计图案，功能性好，而且可以结合常用热处理方式，如退火，热增韧或钢化等方式。涂层厚度范围10-1000纳米。

高反射电光彩：-金或银反射，也可以与玻璃釉料结合装饰

- 功能特点：半透明、半镜面装饰效果
- 易于丝网印刷和数码印刷
- 适合家电（冰箱，烤箱）、家具（淋浴房等）和建筑玻璃第一面装饰，满足EN1092-2标准。

从纳米光滑（低摩擦力）到纳米粗糙的表面结构（原子力显微镜）

防反射涂层（单层）

- 功能特点：减少反射率， $Refl._{Vis} < 1,5\%$
- 容易印刷（丝网印刷）
- 装饰太阳能面板和显示屏玻璃罩
- 满足IEC61215, EN1092-2

这种光谱选择性吸收，适合印刷的涂层可以提高光电电池盖玻璃的性能和质量，同时比其他防反射涂层成本低。这种防反射特点能提高不同波长光的透过率达到4%，同时提高净太阳能获取量和电池效率。

UV 功能性透明涂层

功能特点：通过反射或吸收，阻止50-90%的UV光透射。
容易印刷图案（丝网印刷或数码印刷）
适用于紫外线防护鸟类撞击玻璃

透明导电涂层

- 功能特点：方块电阻： $< 600 \Omega/$ ， $< 200 \Omega/$ （Van Der Paw 方法）
- 在还原条件下：Transm. $> 80\%$
- 容易通过丝网印刷或数码印刷方法印刷图案
- 适合装饰显示屏，电子玻璃，建筑安全玻璃

扩散颜料涂层

- 功能特点：100%阻挡UV光，无镉红色
- 铜扩散深度：2-4米， 1.0 g Cu /m^2

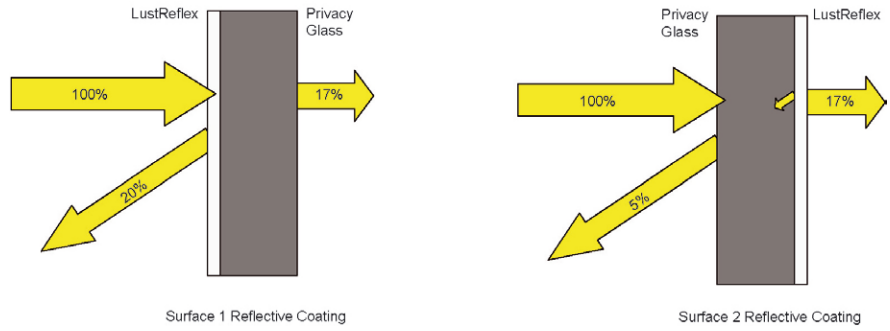


图2

在深色电控调光玻璃上高反射涂层的反射率

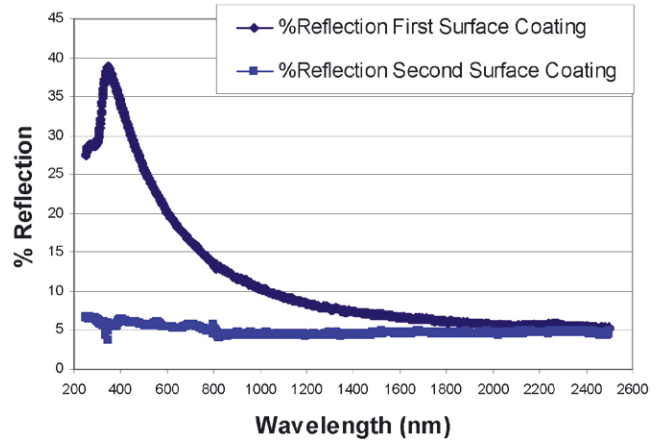


图3

高反射涂层的AFM图片

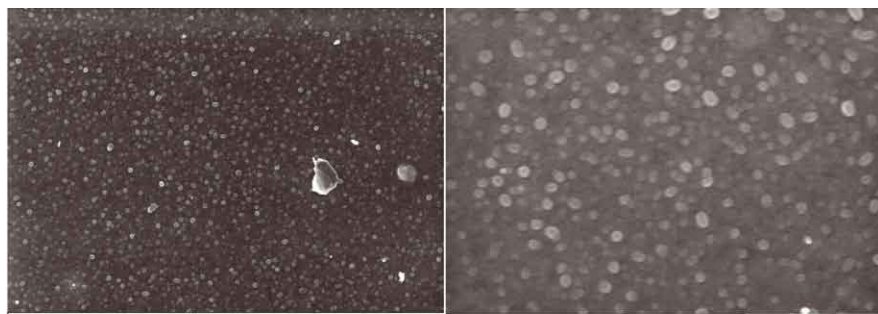
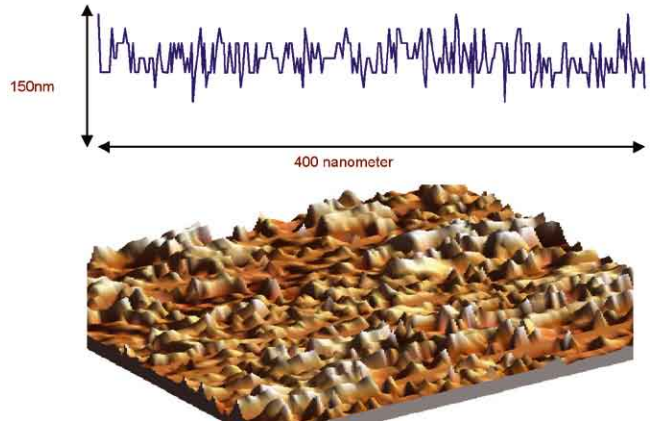


图4

高反射涂层的高分辨率SEM图片

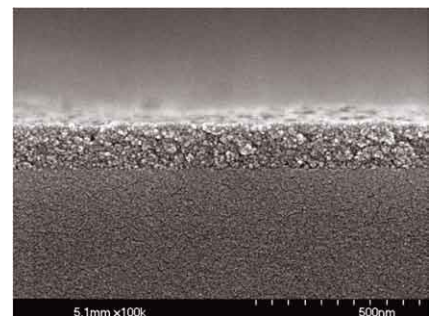


图5

高分辨率SEM 防反射玻璃涂层结构

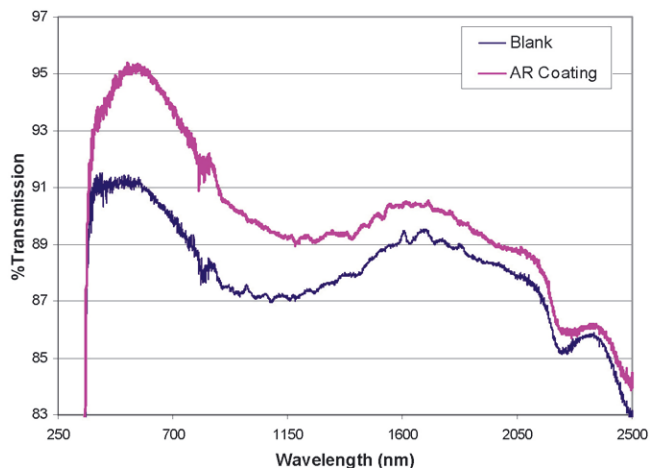


图6
在钠钙玻璃上印刷防反射涂层提高了光透射率

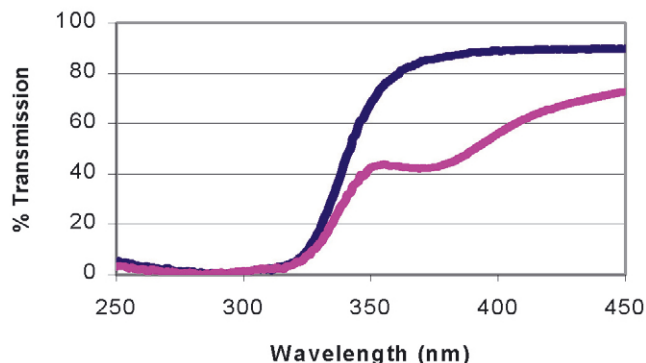


图7
UV反射涂层348-101丝网印刷在钠钙玻璃基体上

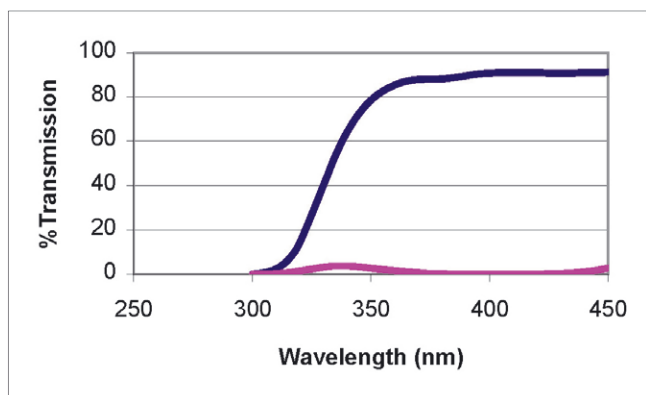


图8
UV吸收涂层348-149A丝网印刷在钠钙玻璃基体上

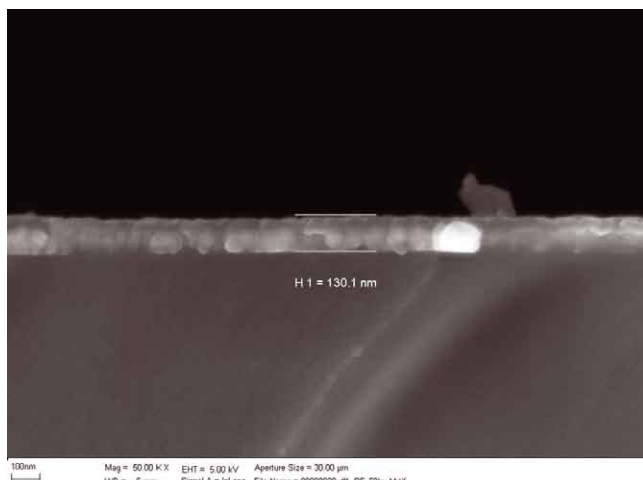


图9
钢化玻璃上丝网印刷TCO涂层的场发射扫描电镜剖面图

- 适合丝网印刷和辊筒印刷
- 适合装饰建筑、家具、容器玻璃
- 满足EN1092-2标准

自组装共价玻璃纳米涂层（低温固化涂层）。利用纳米技术，通过室温水解和缩合反应得到特定的功能。自组装分子交联共价并形成纳米级薄层，可以提高化学和机械性能。硅烷试剂是被典型用到的试剂，客户不同的应用方法需要不同的官能团，激活剂和溶剂/载体。典型的水解和缩合反应实例如下：

在自组装小于500纳米的连续薄层的时候，分子沉积在玻璃基体表面并共价交联。牢固的涂层由包含有 R_mSiX_n 结构的两性分子组成。其中R是非极性或者氟



图10
无镉扩散红色，6毫米浮法玻璃，690℃ 5分钟

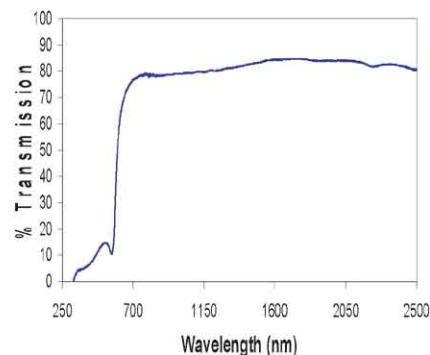
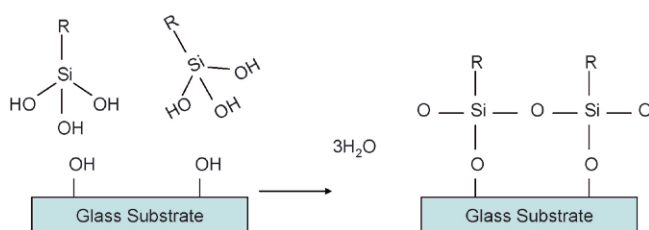


图11
自组装水解和缩合反应



化烷基系统的，有10-30个碳原子， $m+n=4$ ，X是从含卤素，羟基和烷氧基系统中选出来的。

可以得到可见光透射率大于98%的隐形的或可见的透明涂层。R分子两性试剂能降低表面能量，可以防水防油，拥有憎水和疏油功能，使玻璃表面抗污、易清洁、耐蚀性好。机械性能包括耐擦伤性能得到提高。如果长期暴露到在高温，UV光，化学腐蚀和机械摩擦等环境中也会最终侵蚀这些分子涂层。但这些涂层很容易根据需要重新装饰，也很容易在室温下固化。

Ultraséal™

- 光学镜头、实验室器具，餐具的表面涂层
- 建筑ESG, VSG, IGU, 技术玻璃（显示屏），抗污和防涂鸦

浮法钠钙玻璃面板装饰

Clarity UltraSeal™ AB，明显减小动摩擦系数和静摩擦系数。

测试方法：ASTM D1894 速度150毫米/分钟，200克雪橇，2.5平方英寸（16.1平方厘米）。

钠钙玻璃	静摩擦系数	动摩擦系数
没有涂层（控制）	0.34	0.28
装饰UltraSeal AB涂层	0.19	0.17
装饰UltraSeal AB5涂层	0.13	0.12

Defender™

装饰包括汽车挡风玻璃，侧灯。防雨并提高能见度。下雨的夜晚能提高能见度34%。这34%能提高司机1秒的反应时间。如果是60 mph，那就是额外的88英尺，用来刹车或者拐弯或者转危为安的距离。很容易清除冰雪以及虫鸟的粪便。在汽车风挡玻璃上的耐用期能达到6个月或更长。

装饰的涂层已经通过如下化学、温度和UV光测试。

DIN 58196-2	沸水测试-60分钟
DIN 50017 KK	高温高湿：95%的相对湿度，40℃下，144小时
铜催化乙酸盐雾实验	盐雾测试：20个循环
DIN 58196-5	耐磨损测试：粗棉布 50个循环
DIN 58196-6-K2	胶带附着测试
UV 光	30个小时阳光测试，1.1 kw, 820 W/m ²
温度循环	40℃（2小时）到 93℃（2小时）；5个循环
化学耐蚀性能	丙酮，柴油，窗户清洗剂，酒精，软饮料-10分钟



图12

涂层上的永不褪色记号笔迹可以用透明胶带擦除



图13

暴风雨中表面有和没有涂层的玻璃对比

抗酸雨化学耐蚀性能：准备溶液：氨水，NaOH，KOH，和Ca(OH)₂ 加入到自来水中调配成1升溶液。加入H₂SO₄，HNO₃，和HCl调配成1升溶液。阴离子溶液加到阳离子溶液中。阴离子（Cl⁻，NO₃⁻，HSO₄⁻）和阳离子（H⁺，NH₄⁺，K⁺，Na⁺，and Ca⁺⁺）的浓缩液，PH=1。测试前，溶液要充分搅拌均匀，确保所有部分都是悬浮的。装饰涂层的基体浸入到酸雨溶液中，80° C，30分钟，然后冲洗干净，在80° C烘干30分钟，测量实验前后的水接触角。

Clarity Defender™装饰的玻璃面板还要进行盐溶液的测试。在沸腾

的NaCl溶液中浸泡2个小时。实验前和实验后1个小时以及实验后2个小时测试水接触角。

	有涂层	没有涂层
实验前	970	490
浸泡1个小时后	980	380
浸泡2个小时后	940	290

EnergySlayer™

通过捕获IR辐射减少能量负荷。潜在应用：夹层汽车玻璃，建筑玻璃和能量控制窗玻璃。

功能特点：吸收红外光 $T_{NIR} < 40\%$ 。薄层小于25微米，装饰在玻璃或PVB上。高的能见度，光透射率能达到85%。最终涂层玻璃可见光透光率能达到55%到70%。可以通过一层或双层涂层微调光吸收性能。900 -2500 nm的红外辐射，吸收率能达到95%以上，能阻挡95%以上的UV光。

两层混合涂层自组装烧结和固化：Lotus-effect™自清洁玻璃

涂层

功能特点：超憎水、易清洗，防指纹。

装饰：照相机机架，盖片玻璃，或需要防指纹印的触摸屏，自清洁太阳能盖片玻璃。

结论

选择合适的涂层也必须考虑后续的玻璃加工方法如：切割、磨边、退火、钢化和封接等。最后，实际成本可能要超出预算很多，并可能严重影响到玻璃深加工产品的利润。

但另一方面，将来有附加值的玻璃加工产品都需要以快速和经济的方式，采用不同的涂层（镀膜）方法来满足不同客户的需要。这就是今天我们要介绍一系列节能环保新纳米涂层的原因。

References

- [1] source ARKEMA, ICCG7 2008
- [2] M. Lottiaux, C. Boulesteix, G. Nihoul et al., Thin Solid Films 170Z1989.107
- [3] H.K. Pulker, Coatings on Glass, Elsevier, 1984, p. 64-275
- [4] M. Baumann, K. Fritsche, G. Sakoske, G. Tuenker, "Easy Printable Nano Coatings for Glass", Glass Processing Days, Finland 2005, p. 193-195.
- [5] B. Singh, R. Subramaniam, US Patent 5,078,791, Jan 7, 1992
- [6] NanoFilm Ltd, Valley View OH.
- [7] M. Baumann, G. Sakoske, L. Poth, G. Tuenker, "Learning From the Lotus Flower- Selfcleaning Coatings on Glass", Glass Processing Days, Finland 2003, p. 330-333.

QUV Accelerated Weatherometer Exposure Results

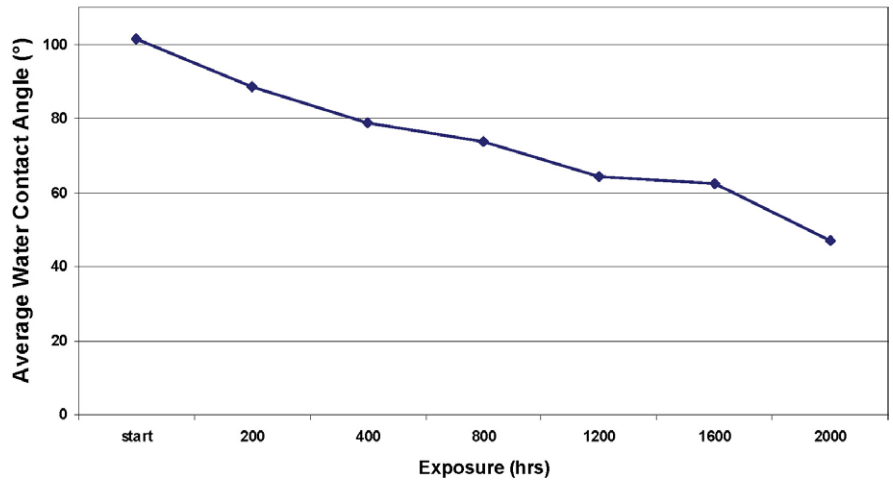


图14
QUV 加速老化试验机测试

图15
有、无纳米涂层的钠钙玻璃酸雨测试

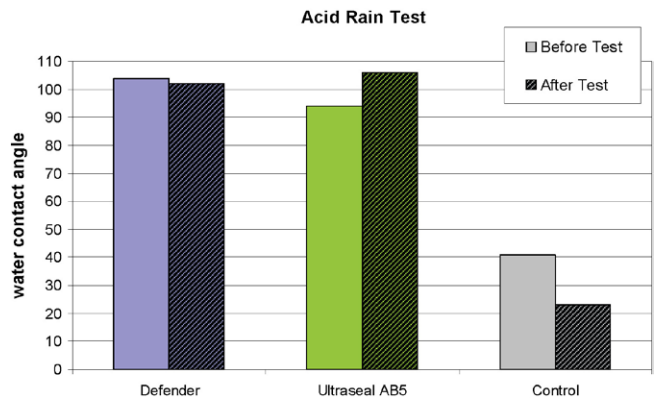


图16
PET上纳米涂层的的选择性吸收红外线性能

