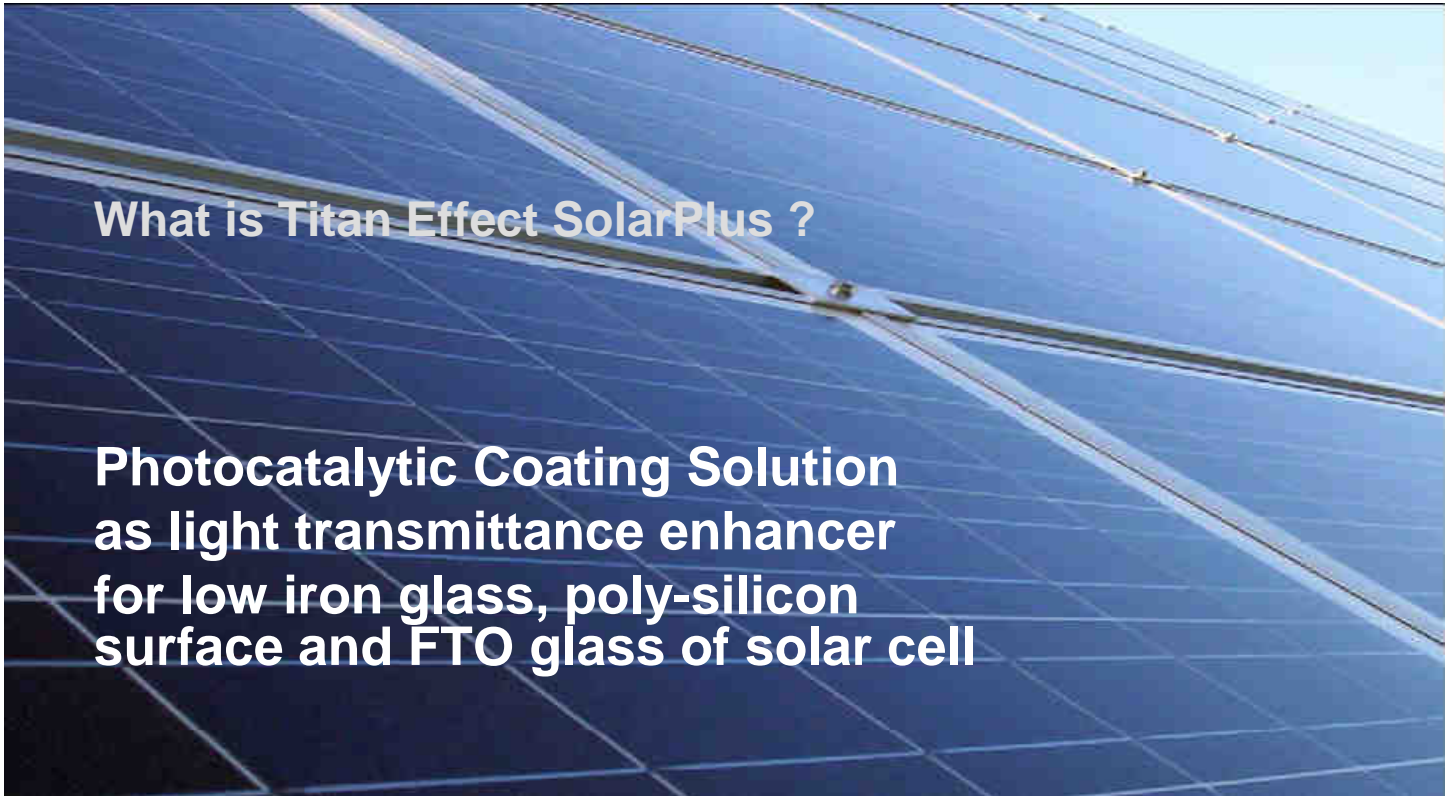




Titan Effect SolarPlus
The Light Clean Revolution

**Especially developed for the
solar panels**

This Technology is protected by the Registered Patent Right



What is Titan Effect SolarPlus ?

**Photocatalytic Coating Solution
as light transmittance enhancer
for low iron glass, poly-silicon
surface and FTO glass of solar cell**

Characteristics

Increasing visible-light transmittance more than by 5%

Increasing power generation by 3%

More cleanliness on surface of solar cell after 1 year, power generation by 7% up

Semi-permanent duration of about 15 years

Reduce Coasts by Self-cleaning and anti-fouling effect, no use of detergents

Eco friendly through Air purification

Appearance	Opalescent colloid
solvent	Water
1st particle size (nm)	15 - 25
Solid contents(%)	1.6 +/- 0.1
pH	3 – 5
Viscosity 20°C	Max 10
Coating method	Spray or dip
Dry/Curing condition	100-200°C 15 min
Shelf Life	6 Months (10-20°C)
Pe,cil Hardness	7H

Titan Effect SolarPlus The Light Clean Revolution

Benefits :

Photocatalyst has Generally two functions. One is the ability of harmful organic gas decomposition into water and carbon dioxide, and the other one is super-hydrophilic effect to prevent contamination from dirty environment.

Titan Effect SolarPlus is specially designed photocatalyst coating system for photovoltaic or solar cell to provide better transmittance and lower reflectance to the conventional solar cell glass.

There are many options to enhance the transmittance or decrease reflectance. However most of the methods are very expensive and complicated like for example forming multi-layers.

Titan Effect SolarPlus offers a very simple method. By the only one spraying, light transmittance increases with efficiency by 5~6% compared with non-sprayed.

Power generation of solar cell depends upon intensity of light through glass. Accordingly increasing intensity of light is proportioned with generation of power.

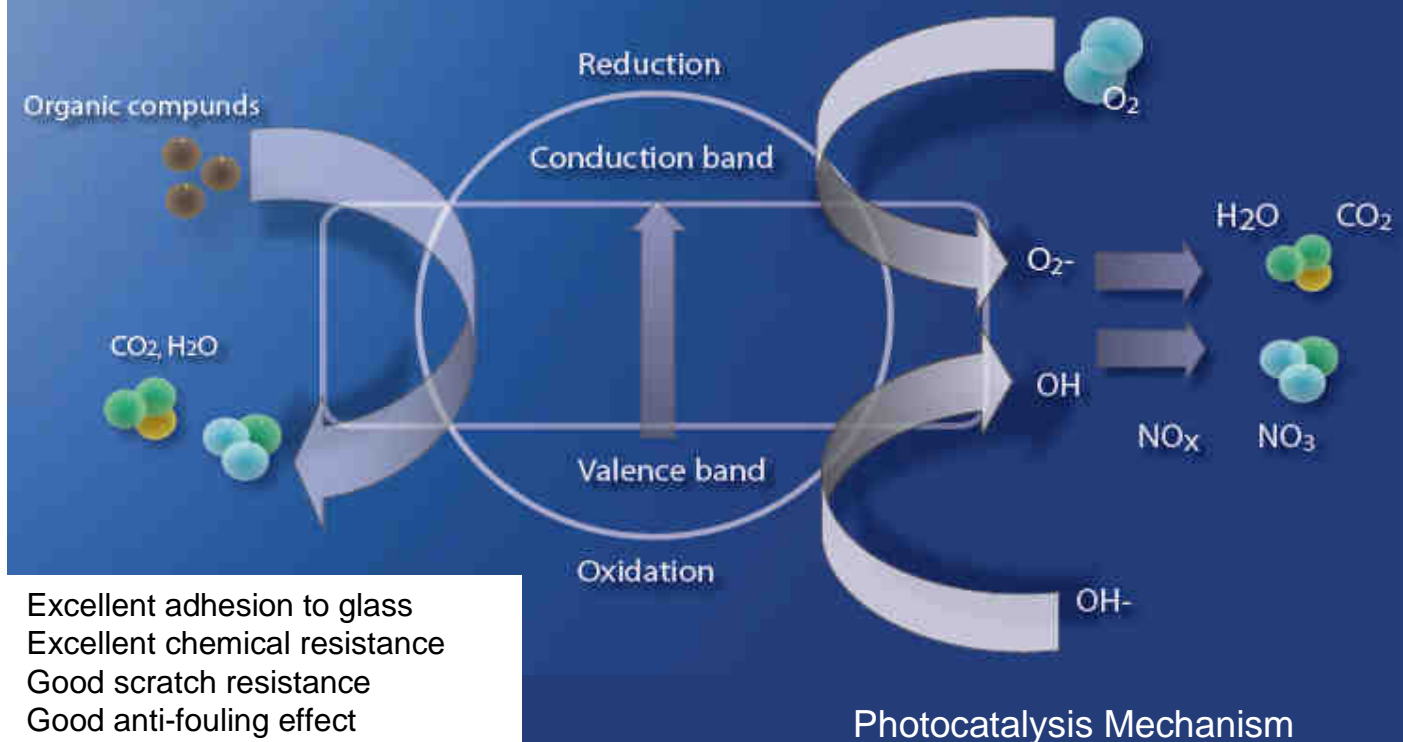
Titan Effect SolarPlus is for :

- Almost Maximum Transmittance and Minimum Reflectance
- Maximum power generation
- Protection of Glass-Surface from the action of natural forces
- Semi-Permanent coating – same as the lifetime of the Panel
- Protection from degradation of dye (DSSC) by reducing of UV-ray
- Simple Coating Process by one Spraying
- Eco-friendly - less frequent use of water and detergents

Titan Effect SolarPlus

Photocatalyst Features

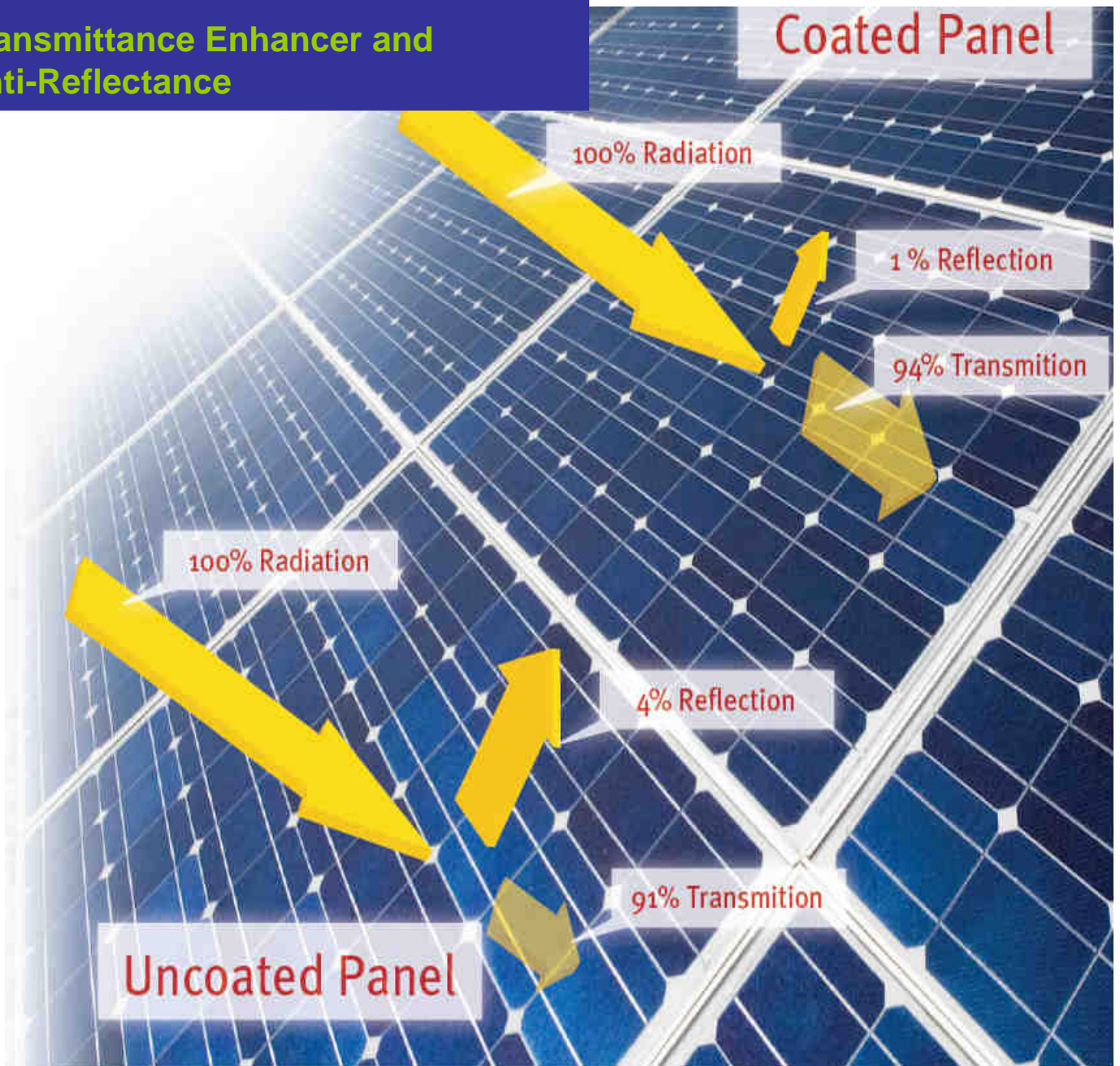
- Improvement of transmittance of glass under sun light
- Self-cleaning and anti-fouling effect with excellent hydrophilic and harmful gas decomposition
-



When Photocatalyst titanium dioxide (TiO₂) absorbs Ultraviolet (UV) radiation from sunlight or illuminated light source (fluorescent lamps), it will produce pairs of electrons and holes. The electron of the valence band of titanium dioxide becomes excited when illuminated by light. The excess energy of this excited electron promoted the electron to the conduction band of titanium dioxide therefore creating the negative-electron (e⁻) and positive-hole (h⁺) pair. This stage is referred as the semiconductor's 'photo-excitation' state. The energy difference between the valence band and the conduction band is known as the 'Band Gap'. Wavelength of the light necessary for photo-excitation is: $1240 \text{ (Planck's constant, } h) / 3.2 \text{ eV (band gap energy) = } 388 \text{ nm}$. The positive-hole of titanium dioxide breaks apart the water molecule to form hydrogen gas and hydroxyl radical. The negative-electron reacts with oxygen molecule to form super oxide anion. This cycle continues when light is available.

Titan Effect SolarPlus

Transmittance Enhancer and Anti-Reflectance



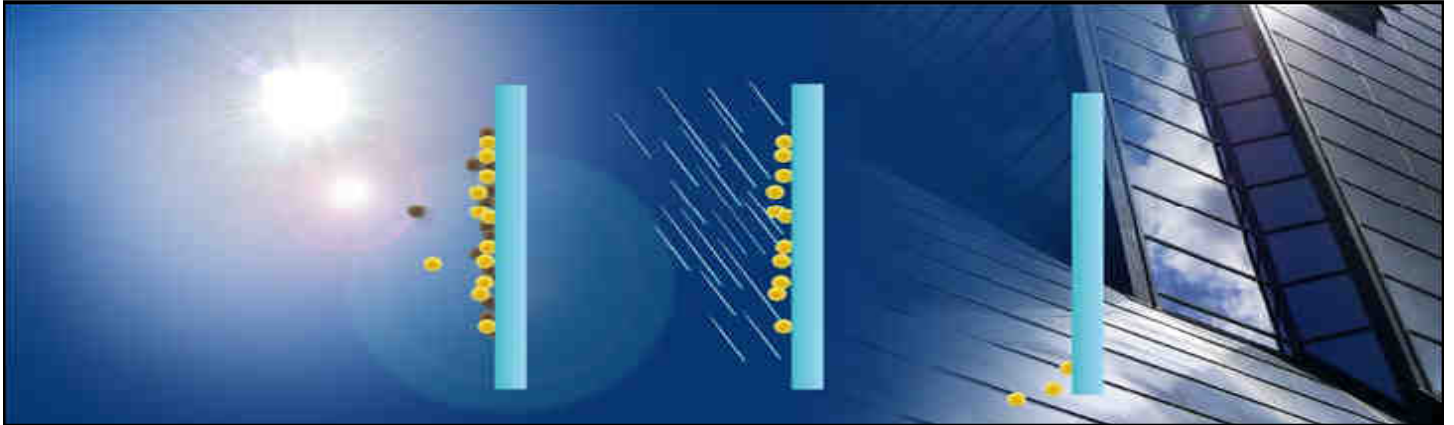
Photocatalyst is composed mainly of TiO_2 and SiO_2 . These materials have different reflective indices compared with of glass. This factor is considerable influence upon the transmittance and/or reflectance.

Titan Effect SolarPlus is worthy of notice in the point of increasing transmittance from the start.

Titan Effect SolarPlus shows transmittance increase and reflectance decrease more than 5- 6%

Titan Effect SolarPlus
Self-cleaning Performance
Super Hydrophilicity

Excellent adhesion to glass
Excellent chemical resistance
Good scratch resistance
Good anti-fouling effect
Excellent Self-cleaning effect



Titan Effect SolarPlus will show the super hydrophilicity feature under light irradiation. The contact angle of the surface will be reduced to $<10^\circ$, which brings 5 benefits of this feature.

1. The water will not form a water drop on the surface when its contact angle is $<10^\circ$, it will form a completely water film. The water will be in flat condition on the surface. This will help to reduce the water strain after rain wash.
2. Generally, cleaning agent reduces the contact angle of water on surface. We call it hydrophilicity feature. **Titan Effect SolarPlus** nano coat's hydrophilicity will simulate this feature and provide better, and so that single water wash on the surface can reach the same effect to traditional washing with detergent. So after a rain wash, the surface will be renew like after a traditional wash with cleaning agent.
3. The hydrophilic feature can keep the water on the surface and the entire surface can be covered with only need a little water. This will prompt its transpiration. So if it is coated on a building wall, the building will need less energy to cool down in summer. If it is coated on a panel in the compressor of air condition, the air condition system will show better efficiency.
4. The dust in the air will be more difficult to absorbing on a super-hydrophilic surface.
5. The hydrophilicity can make the surface with no water drop while raining, so it becomes cleaner in rain.



Titan Effect SolarPlus

Self-cleaning Performance

Photo Décomposition

Processus de décomposition

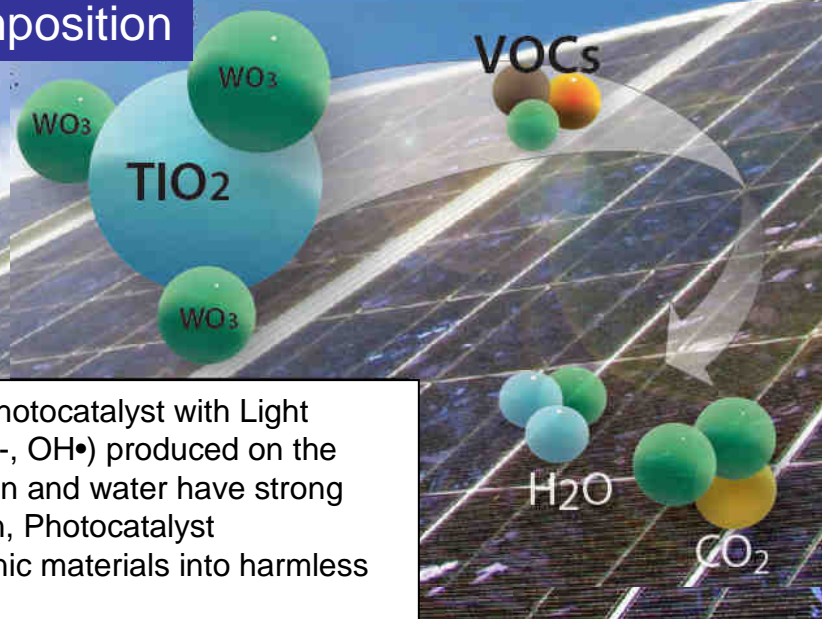


Photo-decomposition by Photocatalyst with Light
 Two activated species (O_2^- , OH^\bullet) produced on the surface of TiO_2 with oxygen and water have strong redox power. By this action, Photocatalyst decomposes harmful organic materials into harmless carbon dioxide and water

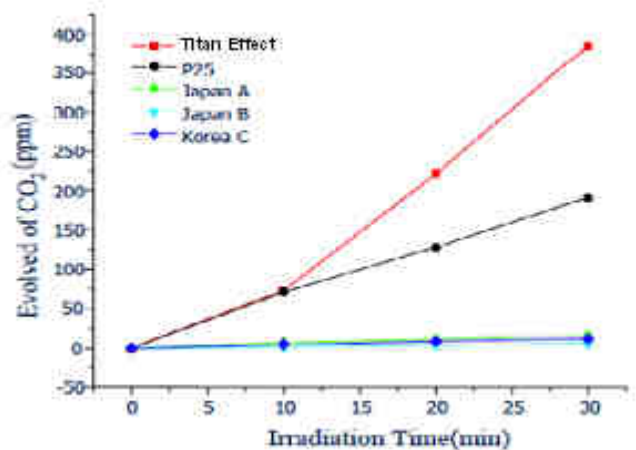
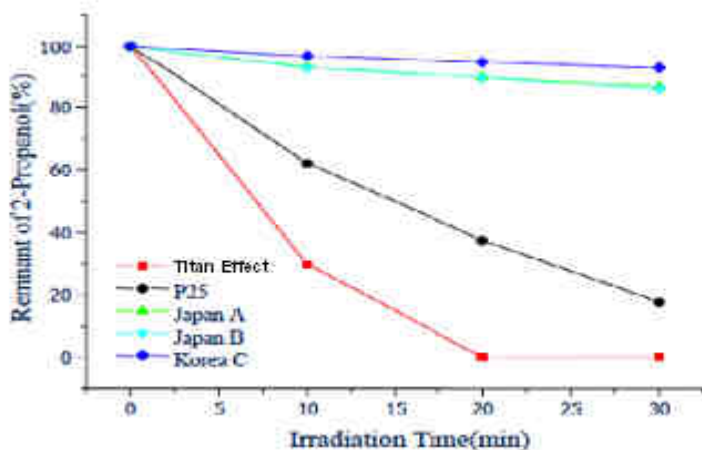
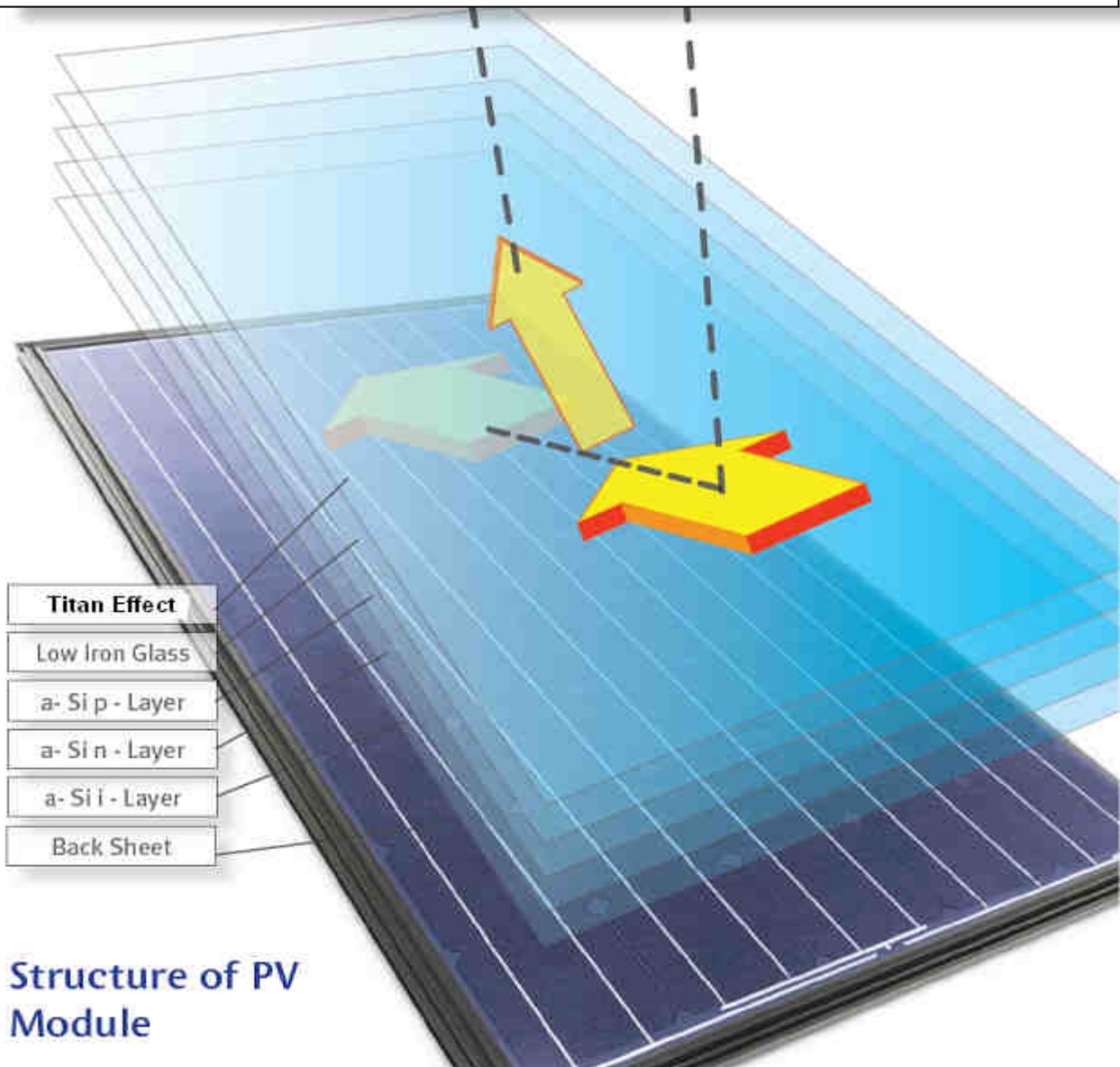
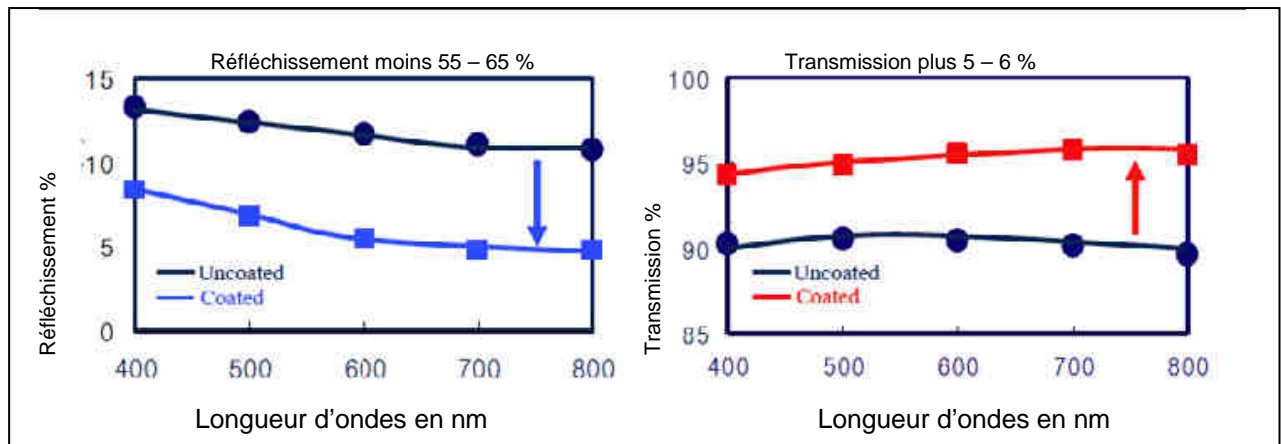
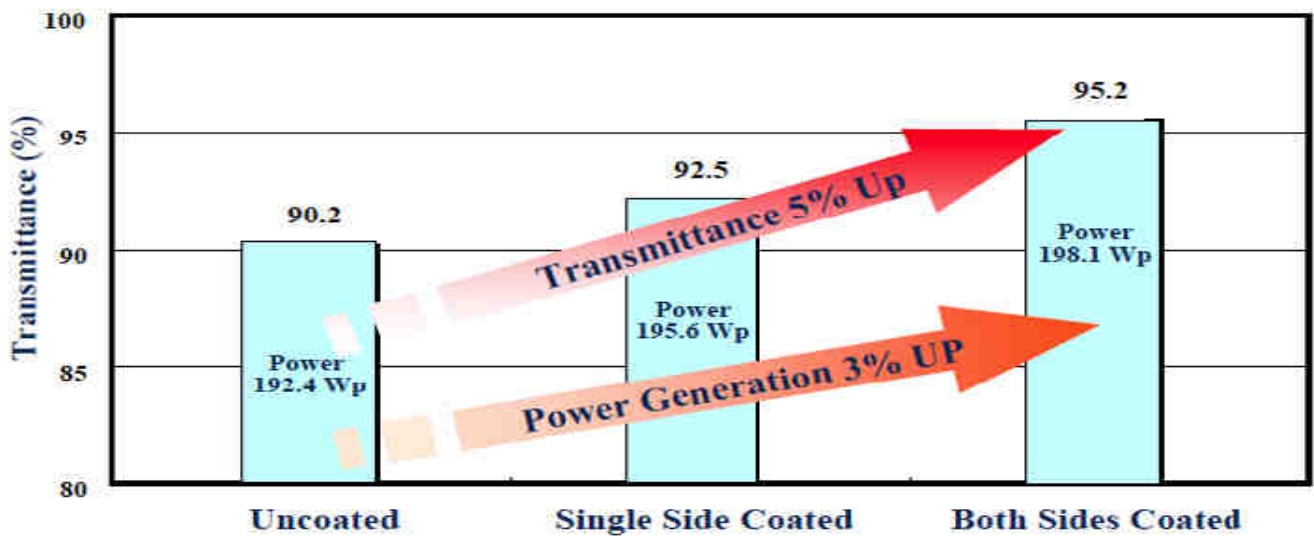


Photo-decomposition of 2-propanol by various photocatalysts. Graph on right side shows that increased CO_2 is generated via acetone from 2-propanol by photo-decomposition

Change of Transmittance and Reflectance after Titan Effect SolarPlus Spray Coating



Measurement of Transmittance and Reflectance by UV-Vis Spectrophotometer



Change of Transmittance and Reflectance between Soda lime glass and Low iron tempered glass by coating both sides

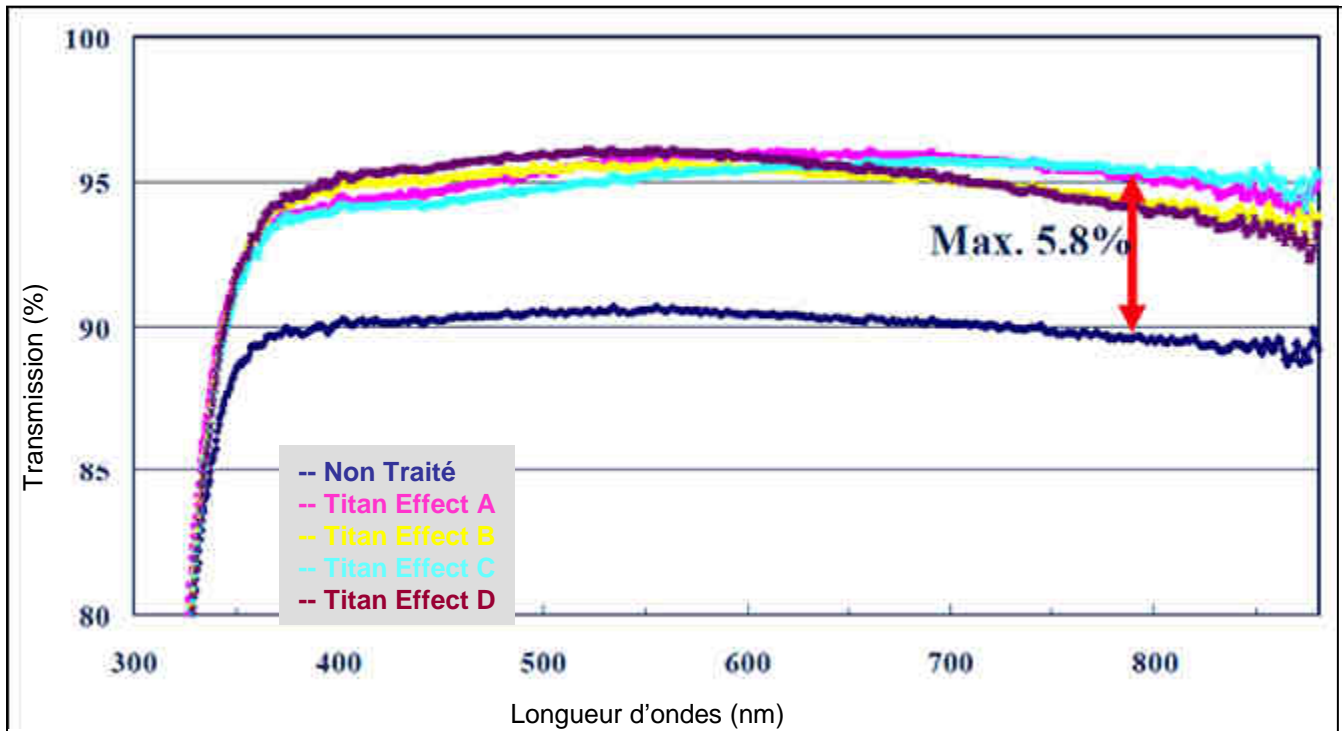
Soda Lime Glass

Longueur d'ondes (nm)	Transmission %		Delta T	Réfléchissement %		Delta R
	Non traitée	Traitée		Non traitée	Traitée	
400	90.6	94.0	3.4	13.3	8.4	4.9
500	91.4	95.6	4.2	12.4	6.6	5.9
600	90.4	96.0	5.6	11.5	5.2	6.3
700	87.7	93.8	6.1	10.4	4.3	6.1
800	84.1	90.2	6.1	9.8	4.3	5.5

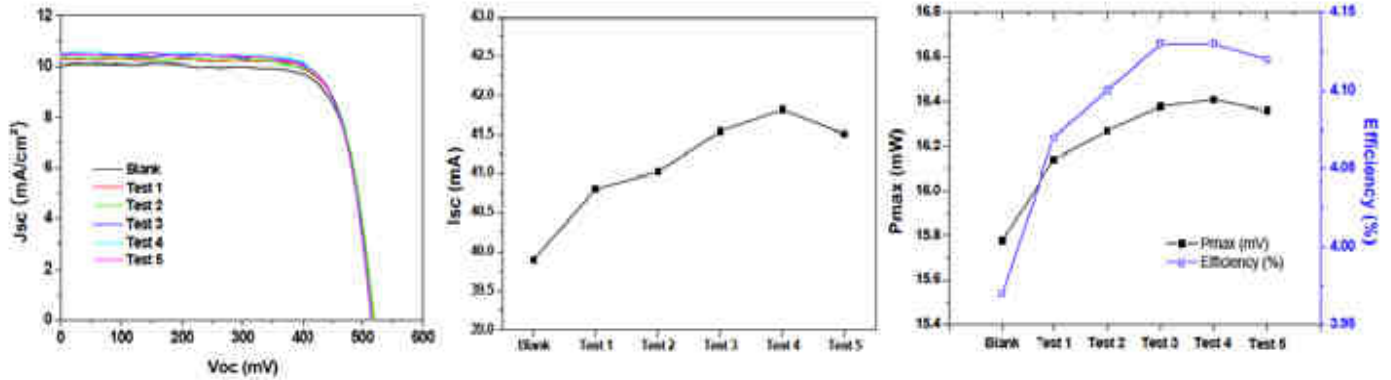
Low Iron Glass

Longueur d'ondes (nm)	Transmission %		Delta T	Réfléchissement %		Delta R
	Non traitée	Traitée		Non traitée	Traitée	
400	90.2	94.2	4.0	13.3	8.3	5.0
500	91.5	94.8	4.3	12.4	6.7	5.7
600	90.4	95.5	5.1	11.7	5.4	6.2
700	90.1	95.7	5.6	10.0	4.7	6.4
800	89.6	95.4	5.8	10.8	4.7	6.0

Transmittance of Low Iron Glass by Coating Volume



Estimation of I-V Curve by Solar Simulation

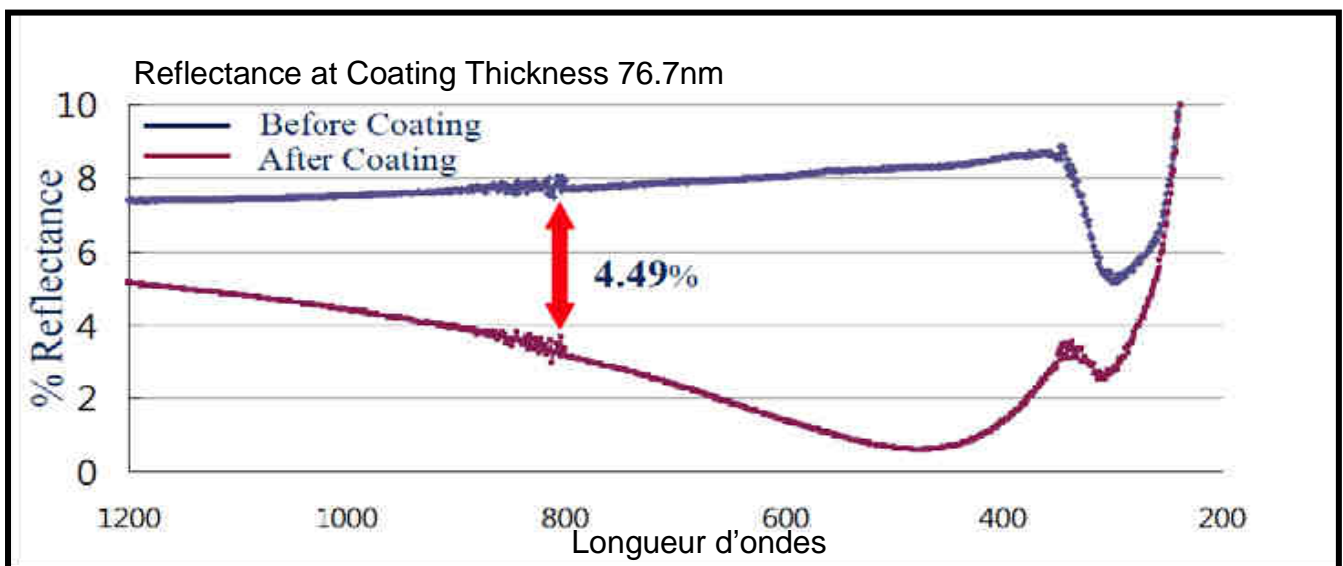
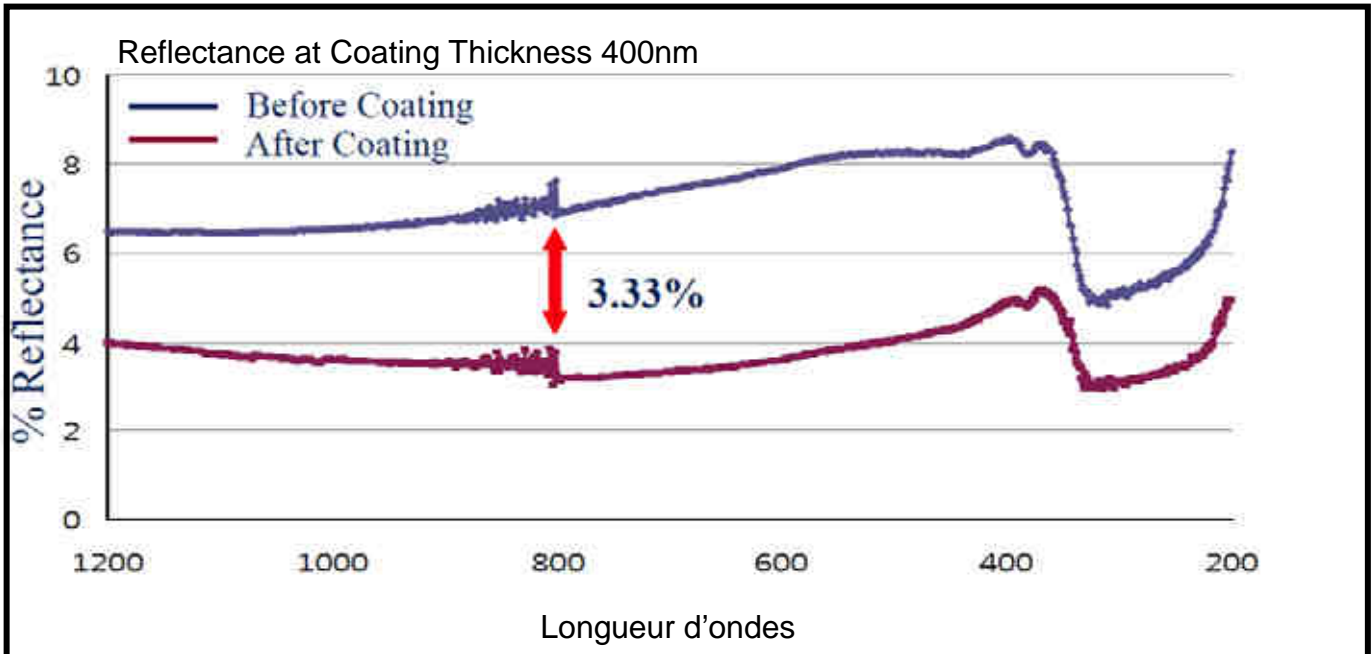


Change of Power Generation by TitanEffect Coating Method on Low Iron Tempered Glass

	Voc (mV)	Jsc (mA/cm ²)	Isc (mA)	Pmax (mW)	Vmax (V)	Imax (mA)	Fill Factor	Efficacité (%)	Augmentation de puissance (%)
Blank	519.202	10.050	39.898	15.780	0.423	37.300	76.18	3.97	0.00
Test 1	519.180	10.277	40.799	16.140	0.423	38.150	76.19	4.07	2.28
Test 2	519.112	10.333	41.020	16.270	0.435	37.400	76.41	4.10	3.11
Test 3	516.035	10.464	41.540	16.380	0.420	39.010	76.43	4.13	3.80
Test 4	515.223	10.534	41.822	16.410	0.419	39.160	76.15	4.13	3.99
Test 5	515.151	10.455	41.505	16.360	0.420	38.940	76.49	4.12	3.68

This data show that power generation increased about 4% by coating method of TitanEffect

Change of Light Reflection by Coating Thickness



Confidence Test of Titan Effect coating Low Iron Glass

Change of Surface on Glass after Damp Heat Test (T°80° C, Hum. 80%, 250 Hrs)

Outdoor Exposure Test

Condition

Place : Bld rooftop
Time : 56 day
(IEC 61215)

Damp Heat Test

Conditions

Temp : 85°C
Humidity : 85%
Time : 1000 Hrs
(IEC 61215)

Test UV

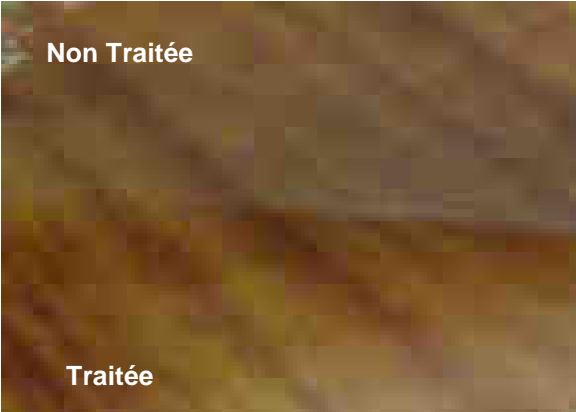
Conditions

Intensity : 25 mW / cm²
Time : 60 Hrs
(IEC 61215)

Résultats (Unités; Wp)

Test	Before Test	After Test	Différence	Résultat
Outdoor Test	204.7	205.3	+0.6	Excellent
	195.2	197.0	+1.8	Excellent
Damp Heat Test	196.9	195.9	-1.0	Good
Test UV	6.764	6.782	+0.018	Excellent

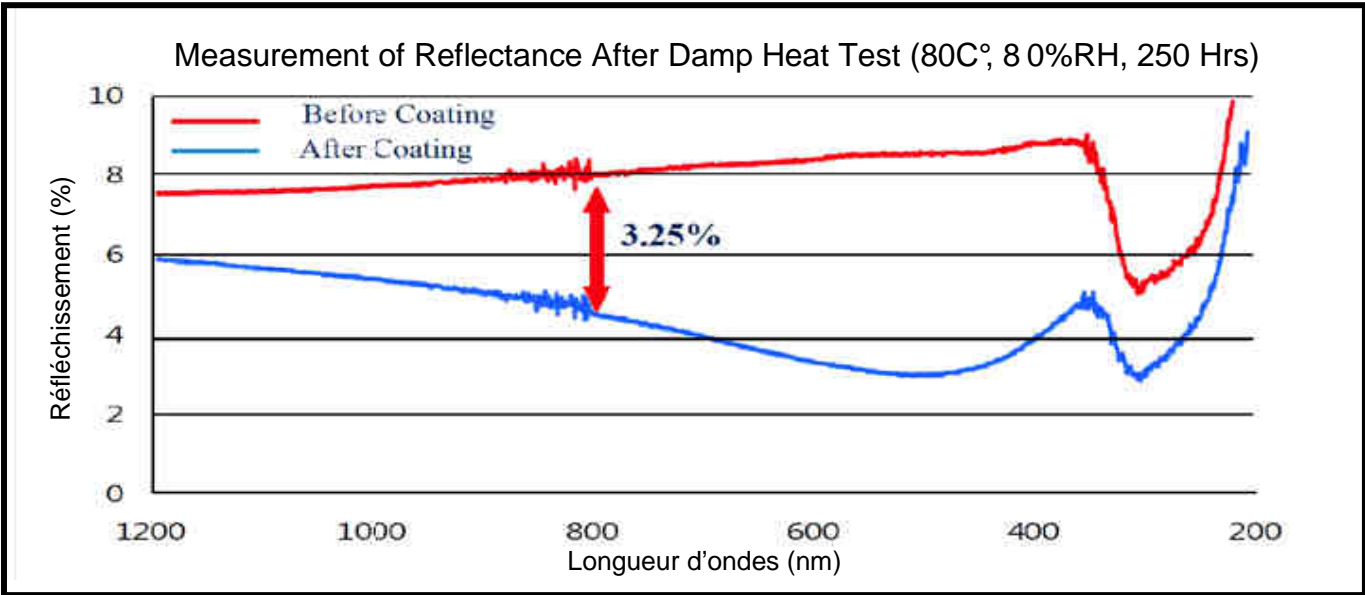
Change of Surface on Glass after Damp Heat Test(80C°, 80%RH, 250 Hrs)



After Environmental Test Uncoated surface becomes cloudy whereas coated surface remained almost same. This means that the coating material prevents migration of sodium ion from inside of glass to surface.



Uncoated Surface became hydrophilic by the migration of sodium ion after Environmental test



Environmental Test by Q-UV

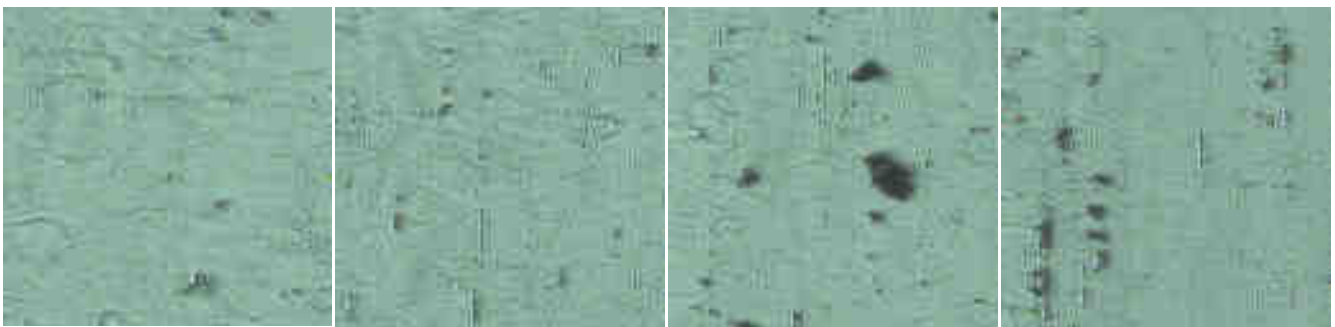
(Conditions : Q-Lab, UV-B Lamp, 0.67W/m², 60C)

No Serious Defect was reported compared with initial state during Q-UV Test .

Change of Water Contact Angle during Q-UV Test			
Temps (Hrs)	Uncoated	Coating (60ml/m ²)	Coating (100ml/m ²)
0	22.0	<5	<5
400	28.7	<5	<5
800	34.5	<5	<5
1200	47.9	<5	<5
1600	52.4	<5	<5
2000	53.8	<5	<5
2400	58.0	10.5	<5
2800	58.6	17.4	<5
3200	55.7	20.5	5.8
3600	53.2	20.5	14.2
4000	55.3	21.8	16.2

Test of Pencil Hardness after 4,000Hrs by Q-UV Test

Spray Coating with 60ml/m²

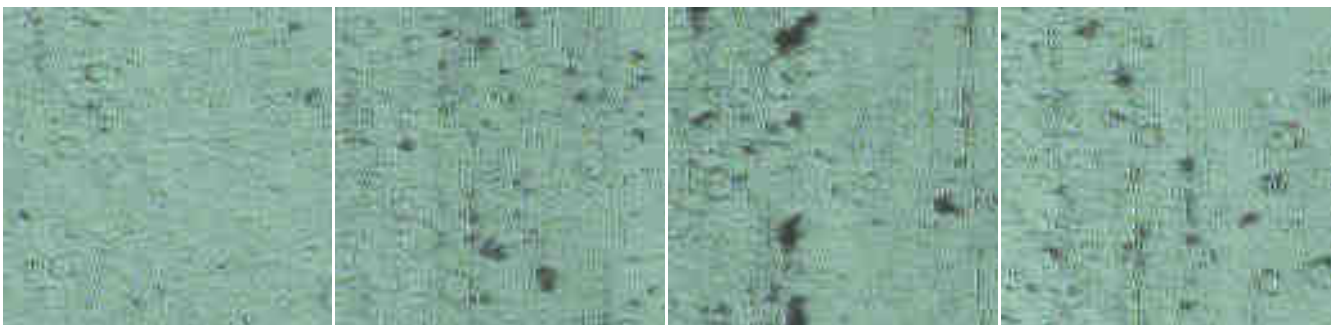


Surface traitée

Pencil – 7H

Pencil – 8H

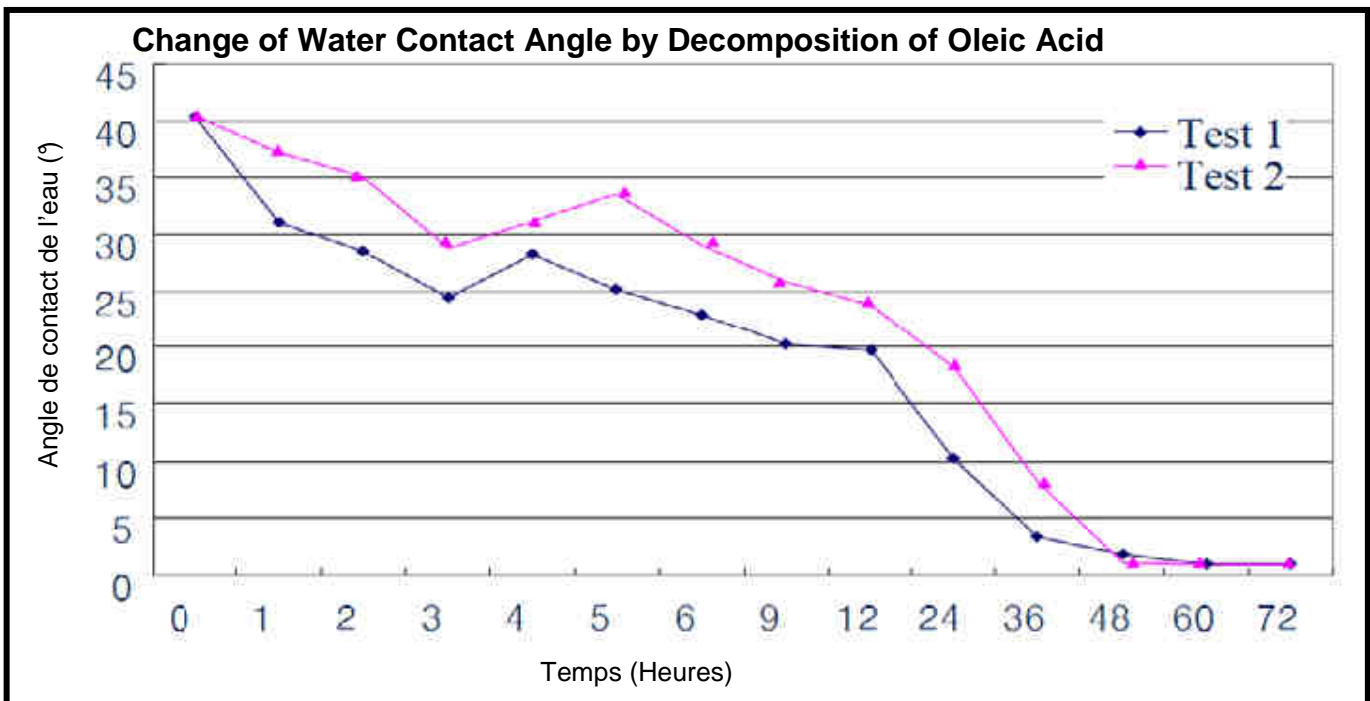
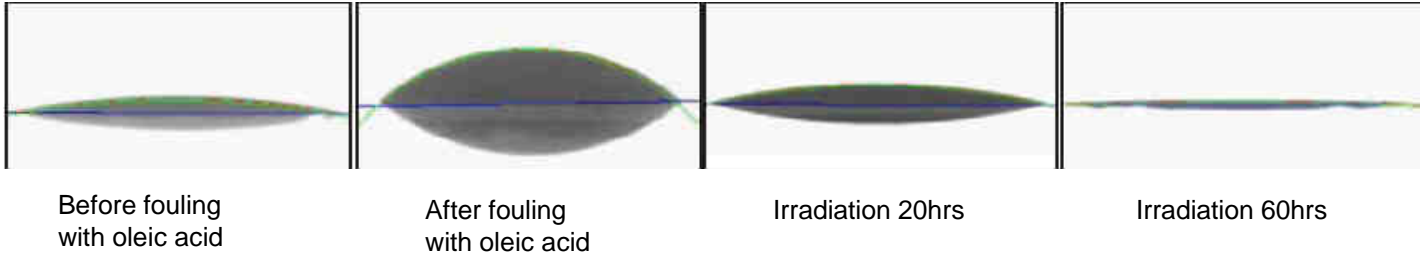
Pencil – 9H



Spray Coating with 100ml/m²

Self-Cleaning Effect (Anti-Fouling Effect)

Photo-decomposition of Oleic Acid by ClearSolar



Cross-cutting Test (Adhesion Test)



- Test condition
- ASTM D3002, cross cut tester (width 1.0mm, 10 x10)
- Substrate: Soda lime glass coated with ClearSolar by spray

Abrasion Resistance Test

1) Test Method

Rubbing Material ; Cotton Cloth

Loading Weight ; 500g

Moving Distance ; 100mm

Number of Cycle ; 30 Cycles

The Scheme of Abrasion Test for ClearSolar Coated Glass



Verre traité Titan Effect

Substrate				Coating layer peeling)	Remark
Glass	0 cycle	10 cycles	30 cycles		
	6	7	8	no	Spray

* Uncoated glass : $\theta = 43^\circ$



(a) Uncoated glass



(b) 0 cycle



(c) 10 cycles

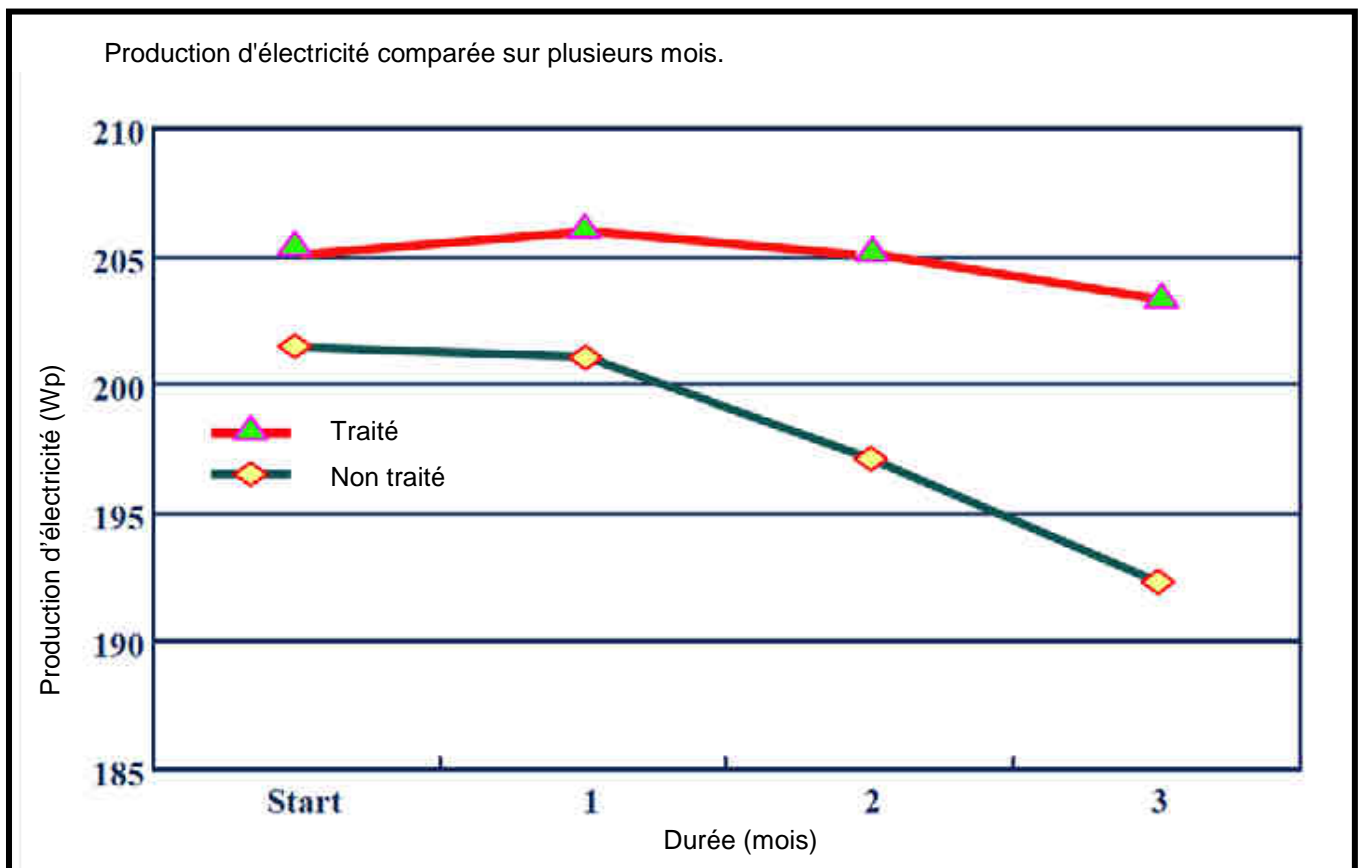


(d) 30 cycles

Analysis of Water Contact Angle after Abrasion Test with TitanEffect Coated Glass

Generally Effect by Titan Effect

Basically in outdoor experimental, Titan Effect coated PV module shows about 3% increased power generation rather than uncoated PV module through increased transmittance at initial stage. After a lapse of 3 months, the difference of power generation between Titan Effect coated module and uncoated module indicates more than by 5% by self-cleaning effect



Power generation of each PV module between uncoated and Titan Effect coated with the passing of time

Three creative economic benefits; firstly, more power generation by the increase of initial transmittance, secondly, more power generation by self-cleaning effect and finally environmental protection from air pollution covers the initial expense of photocatalytic treatment

Expense of Photocatalytic treatment

Power Generation by increased Transmittance

Power Generation by Self-cleaning

Environmental Protection from Air Pollution

Summary of Properties of Titan Effect

Power Generation	200Wp level Module	3% <
Transmittance	Low iron Glass, 3.0mm	5% <
Reflectance	Low Iron Glass, 3.2mm	4% <
Outdoor Exposure	50 jours	Excellent
Damp Heat Test	Temp 85°C, Hum 85%	Good
Test UV	25mW/cm ² , 60Hrs	Excellent
Test Q-UV	0.67W/cm ² , 4400Hrs	Excellent
Adhesion test	ASTM D3002	Excellent
Pencil Hardness Test	Wt. 1000g	Good
Abrasion Test	500g x 30 cycles	Excellent
Hydrophilicity Test	Acide Oléique	Excellent



**Photocatalytic Coating Solution as light transmittance enhancer
for low iron glass, poly-silicon surface
and
FTO glass of solar cell**