Polysil®

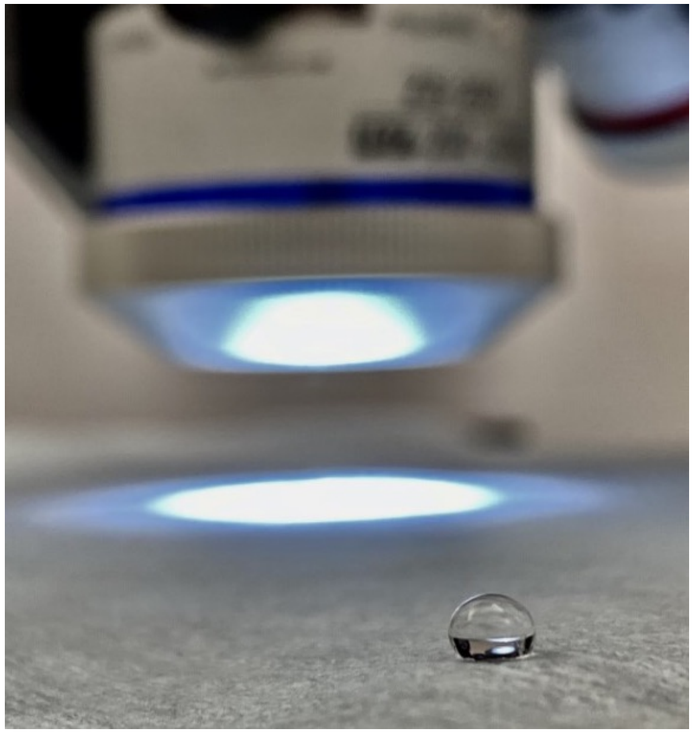
The nanotechnological evolution of coatings

Nanoprom Group: Italian Quality and Vision

Nanoprom is an Italian company, pioneer in research and industrial application of nanomaterials for functional coatings. Since the late '90s, the company is active in research about innovative sol-gel process and developed Polysil®.

Qualifying information about Nanoprom:

- ISO 9001, ISO 14001 and EN 9100 certified.
- Nanoprom manufactures Polysil in its own facility and is the sole manufacturer and distributor.
- Polysil coatings are protected by 8 patents as well as the trade secret on the fabrication process.
- Nanoprom is founding member of the ANSER consortium, formed by a group of leading companies supplying “Made in Italy” technologies for the aerospace and aeronautics sectors. https://www.anser-it.it
- Nanoprom is Industrial Research Laboratory of Emilia-Romagna High Technology Network



Health and Environment

Nanoprom develops its own proprietary products with full respect of health and environment. All the components used in Polysil formulations are subjected to environmental, toxicological and safety controls. In addition, the resulting nanostructured coatings top-level safety is ensured by numerous severe tests passed before introducing them to the market.

In a nutshell, all Polysil family products guarantee health and environment protection for the following reasons:

- The starting components are non-toxic.
- Only strongly bonded nanolayers and nanocomponents are used.
- The spray drops are not breathable.
- The nanostructured coatings adhesion on surfaces is high, ensuring against delamination.
- Even if particulate was released, it would be non-toxic

The Nalucoat process, developed by Nanoprom, is designed to make environmentally sustainable and recyclable aluminum components.

Reduce the Carbon Footprint

The main surface coating technologies used in industry were analyzed, and the results were quantification of the pollution produced by Polysil and treatments currently on the market, expressed in kg CO2 equivalent. This, was assessed for both the production of the product and the user application phases of the product (end-of-life impacts were not examined).
The results can be seen in the image: Polysil coating had 50% less CO2 equivalent of standard paint.
In addition to reducing CO2 equivalent, it must also be taken into account that metal parts that are subjected to electroplating processes are often overpainted increasing the CO2 footprint and are not recyclable directly but must be treated as special waste.

Another element to take into account is process efficiency; an electroplating treatment has a discard rate, due to differences in bath placement, variations in process parameters, and concentrations of active elements, that can range from 20 percent to 75 percent depending on the customer's acceptability criteria. In contrast, parts processed with Polysil (which replaces galvanic processes) have a defect rate around 2 percent, moreover, nonconforming parts can be reprocessed by zeroing out scrap (an operation not feasible with galvanic processes).

Treatment of 1 m² of metal surface with Polysil

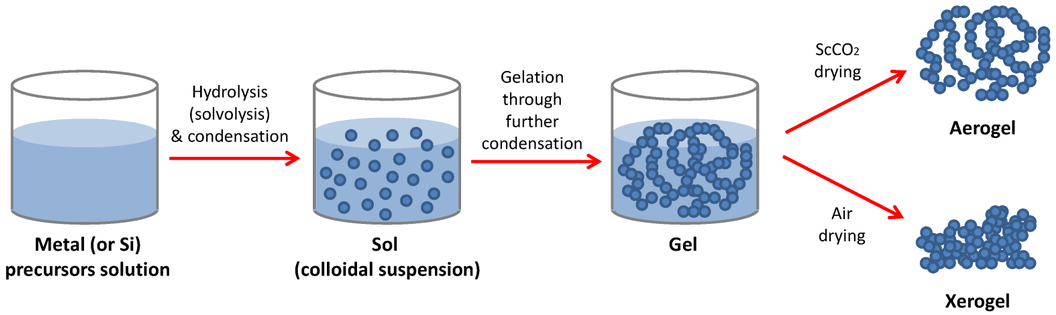
Treatment of 1 m² of metal surface with traditional varnish

Treatment of 1 m² of metal surface with chrome plating

Polysil® the "Liquid Glass"

SOL-GEL PROCESS

- After spraying, nanoparticles are arranged on the surface in self-organizing thin layers.
- Polysil-based coating cures thanks to moisture presence in the air or heat. Typical layers can range from 2µm to 20 µm.



APPLICATION FIELDS

- Automotive/motorsport
- Naval
- Aerospace
- Mechanics
- Design

MAIN FEATURES

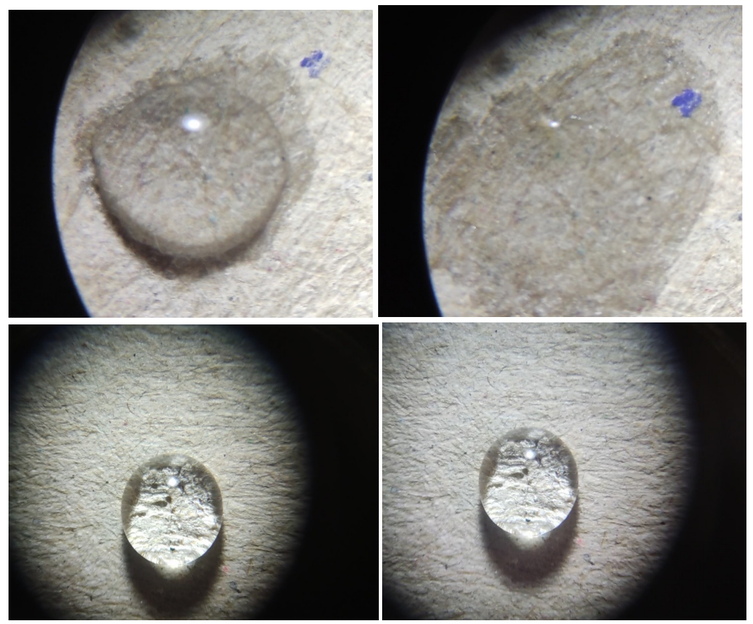
- Room temperature process.
- Possibility to functionalize the coating with nano additivities.
- Lightweight due to low coating thickness.
- Covalent adhesion to some substrates.

Polysil Paper for Cardboard Hydrophobization

Nanoprom Chemicals has developed and tested Polysil Paper, a coating to protect paper and paperboard from water and moisture. The coating is based on patented sol-gel processes, Polysil Paper creates cold vitrification on the substrate by following surface micro-movements without altering the structure and providing total and effective protection from water.
Polysil paper has unique advantages over other surface treatments:

- is the best choice for eliminating plastic in cardboard packaging;
- is completely recyclable;
- is a food-tested product;
- imparts several properties to the treated substrate, including high hydrophobicity, which is crucial here as it makes the cardboard water-repellent. It also confers resistance to acids (from pH=2 to pH=11).

In the picture at drop after 10s and 120s on untreated cardboard (top) and on treated cardboard (bottom)



Food contact test

Simulating liquid	Result (mg/dm^2)	Maximum allowable limit (mg/dm^2)
Distilled water	1.0	8
Acetic acid (5% in water)	2.0	8
Ethanol (15% in water)	1.5	8

Tests were conducted on steel sheets surface-treated with Polysil Paper in accordance with the standards UNI EN 1186-1:2003 and D.M. 21/03/1973.

Polysil SC for Metals Corrosion Protection

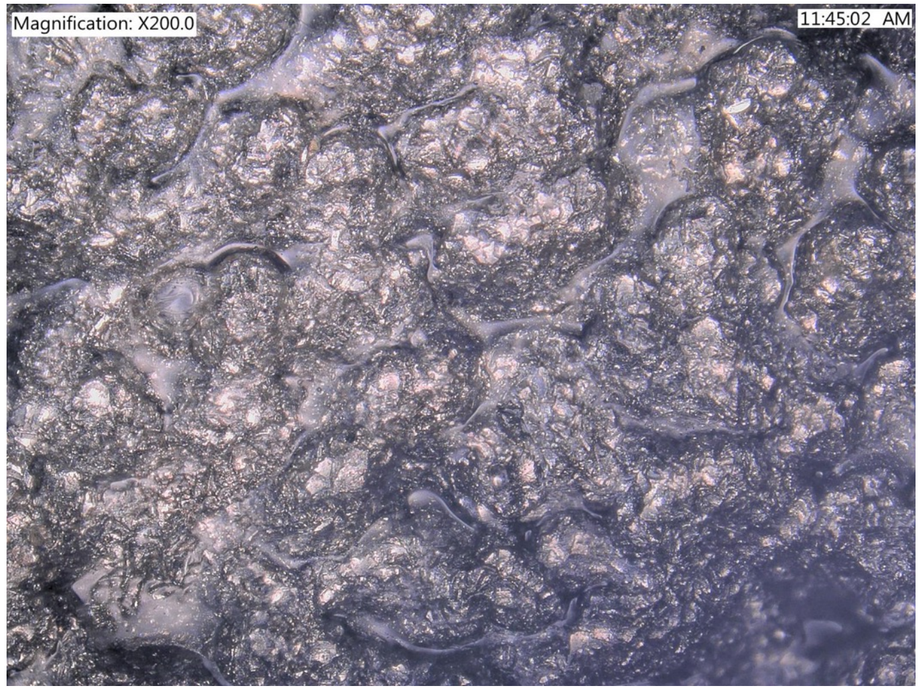
Thanks to its composition and hydrophobic characteristics, chemical inertia and surface hardness, Polysil coatings are inherently corrosion resistant.

Due to its filmic properties, Polysil coating is also excellent as an anti-corrosion treatment for Additive Manufacturing parts. High surface roughness makes usual protection methods (chromating, passivation, etc.) ineffective, as the surface treatment cannot adequately protect valleys due to surface roughness.

Extensive tests on aluminum and steel samples have shown that both as-built and machined Additive Manufacturing parts coated with Polysil resist salt spray without corrosion evidences for 168h.

Further developments have resulted in Polysil SCC and SCC+, which has excellent corrosion protection performance, as shown in the table.

***SS**: Salt Spray*
***CASS**: Copper Accelerated Salt Spray*

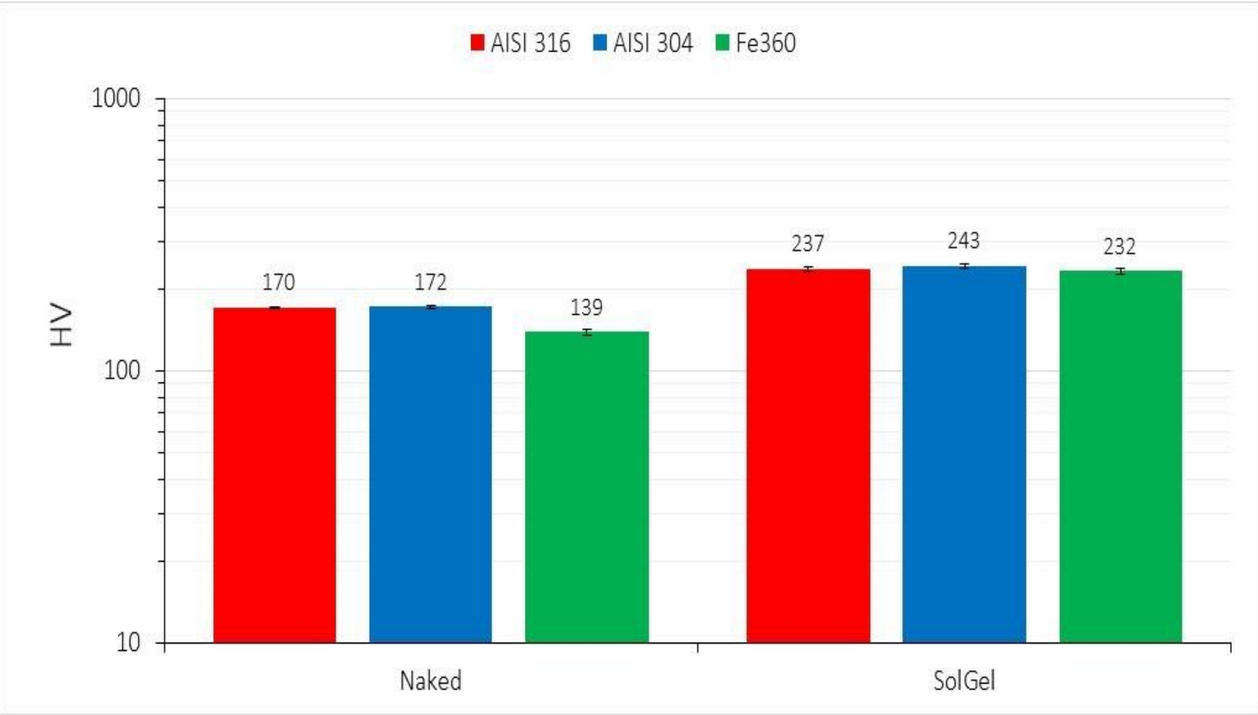


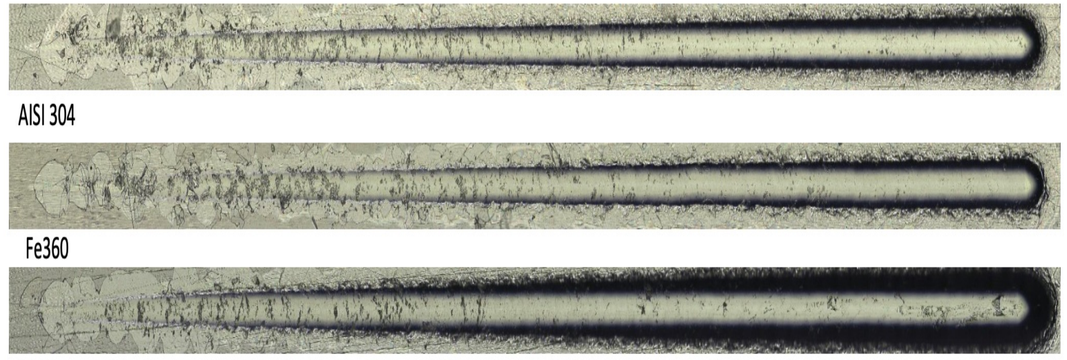
Corrosion Test on aluminium alloy	Polysil SC	Polysil SC+	Polysil SCC
SS Test	> 200 h	> 400 h	> 800 h
CASS Test	> 8 h	> 36 h	> 72 h

Metal surface hardness increase

In addition to its excellent anti-corrosion properties, inorganic Polysil gives it a high surface hardness, without delamination phenomena:

- AISI316 steel: the hardness of the surface goes from 170 Vickers to 237 Vickers
- AISI304 steel: the hardness of the surface goes from 172 Vickers to 243 Vickers
- Fe360 steel, the hardness of the surface goes from 139 Vickers to 232 Vickers





Polysil for Lightweighting

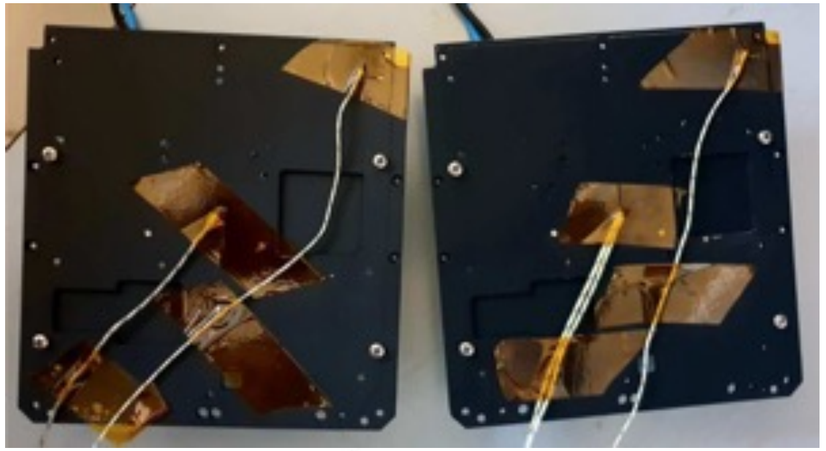
Thanks to its low thickness, Polysil makes it possible to create ultra-lightweight coatings that save up to 85% weight compared to conventional epoxy coatings.

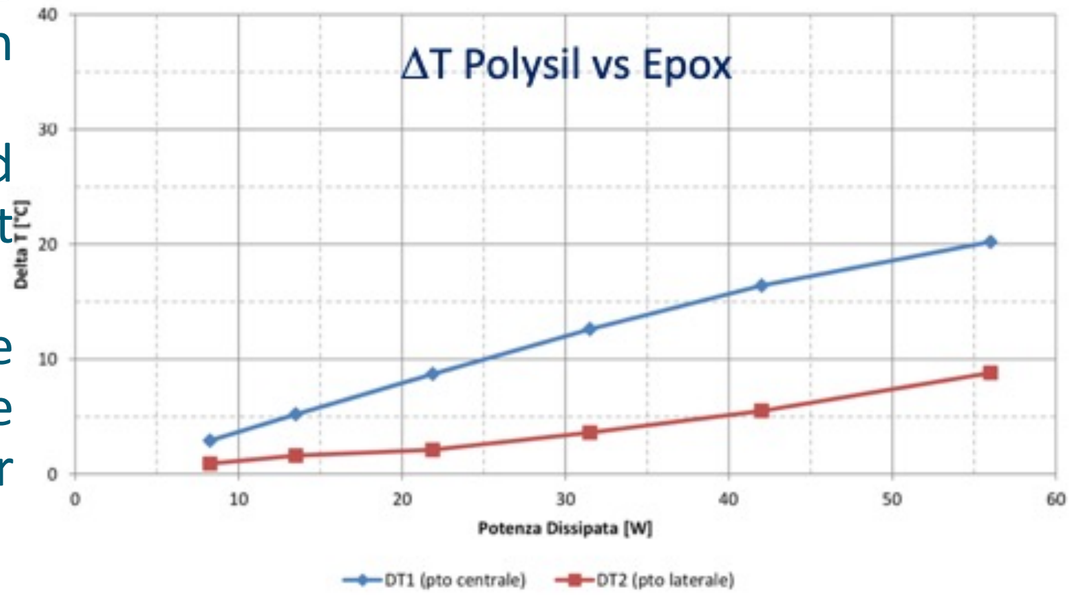
As examples we can show some use cases:

- coating of racing rims: for each rims, the coating weight is reduced from 250 g to 50 g (unsprung masses) with a weight reduction of 80%;
- body painting: when used on cars for endurance racing (WEC), the weight of the paintwork has been reduced by more than 5 kg;
- aerospace: use on an ultralight helicopter allows the paint weight to be reduced from 7.8 kg to 0.900 g with a weight reduction of 86%;
- aerospace: Polysil coating applied to the surface finish of UAVs makes it possible to reduce paint weight by more than 78%.

Polysil Thermal

Polysil was combined with graphene to boost Surface Thermal Conductivity, to create **Polysil Thermal**
The finely dispersed graphene nanoplatelets into the Polysil matrix greatly enhance heat exchange (**irradiation and surface conduction**), boosting thermal dissipation performance of the substrate.
In the picture, the temperature of the frame treated with Polysil thermal is considerably lower than the epoxy paint frame, due to much better heat emission obtained thanks to this thin coating.
The temperature difference between Polysil-treated and epoxy paint frames is more evident at the central point where the thermal source was applied.
The use of the Polysil reduces the temperature difference between the central and lateral point of the frame (more uniform temperature) due to better surface heat transmission.





Polysil Thermal applications

Cases of application:

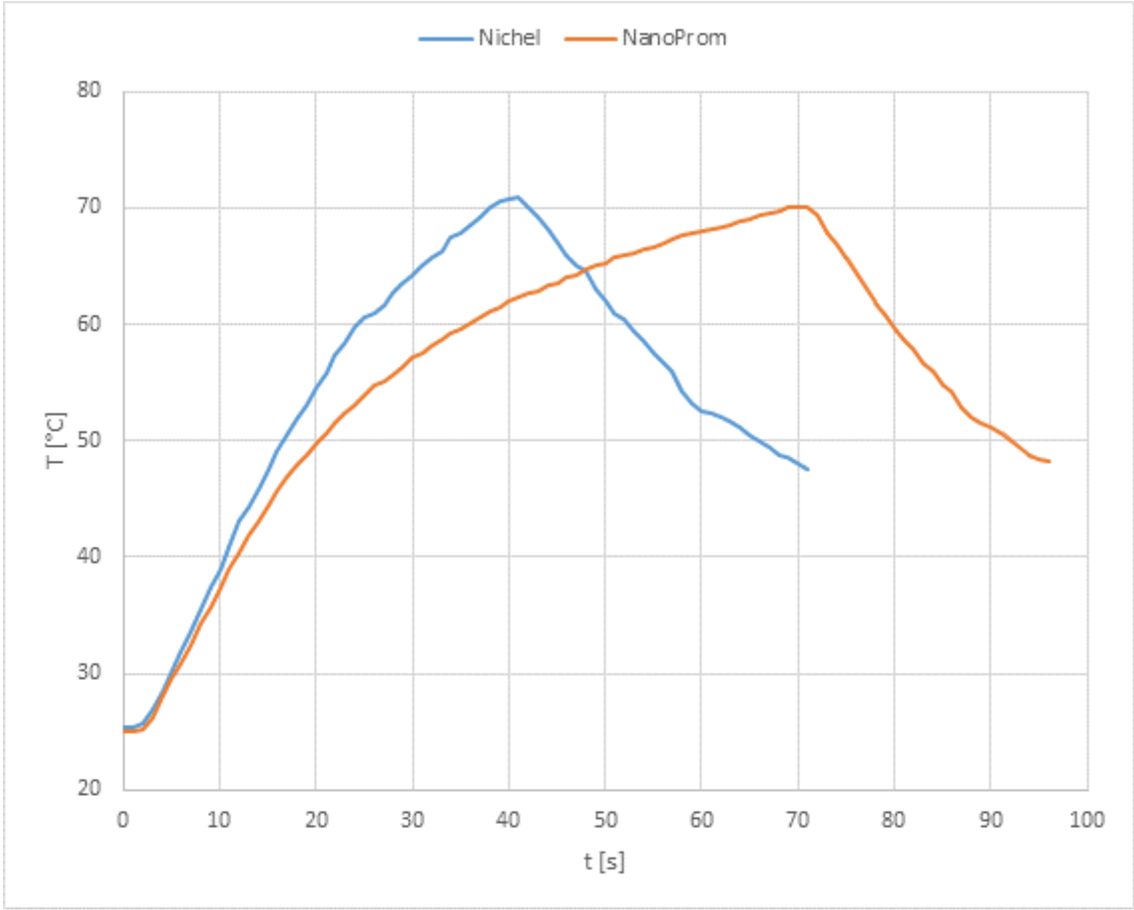
- Aluminum chassis containing power electronics: in standard operating conditions, at 25°C, data confirmed a temperature decrease from 60°C to 55°C, thanks to Polysl Thermal coating.

- Electric motors with aluminum case: data confirmed a temperature reduction up to 15°C (from 100°C to 85°C) upon coating with Polysil Thermal on external surface. In addition, the anticorrosive properties of Polysil coating allow for the elimination of anti-corrosive galvanic treatments.

Polysil Graphene

Polysil Graphene, with its higher graphene concentration (> 2,5 wt%) in Polysil matrix, can further enhance heat exchange (irradiation and surface conduction), boosting thermal performance of the substrate, since nanoplatelet are still finely dispersed, thanks to unique characteristics of Polysil.

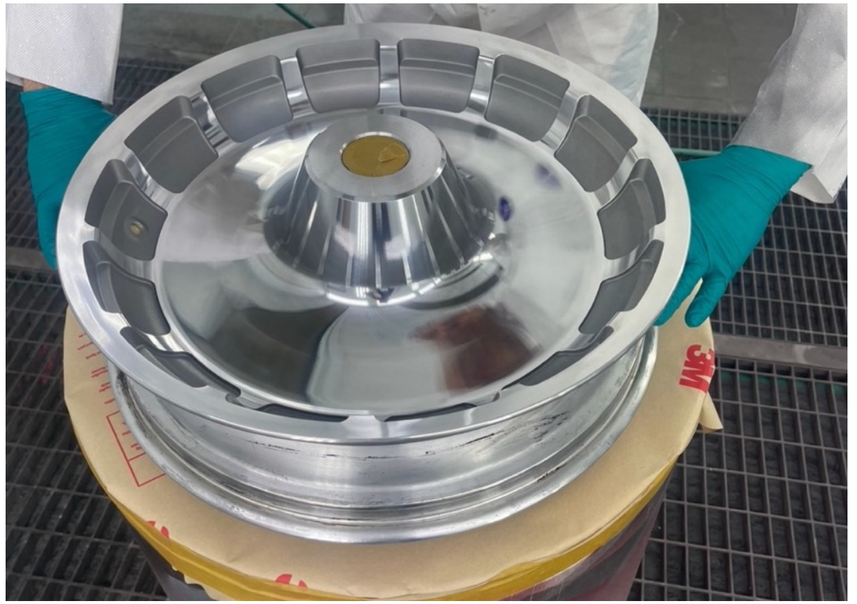
At high concentration, graphene ensures a high thermal conductivity (about 10W/mK) and a fair electrical conductivity, allowing this coating to be used both for electromagnetic shielding and for improving heat transfer, while also guaranteeing fire retardancy (e.g. on SMC battery boxes). The excellent oxygen impermeability of inorganic Polysil and the ability of graphene to function as a hydrogen barrier, allow this coating to be used effectively to protect metal parts from degradation induced by exposure to hydrogen or oxygen.



Polysil Alu in Nalucoat process

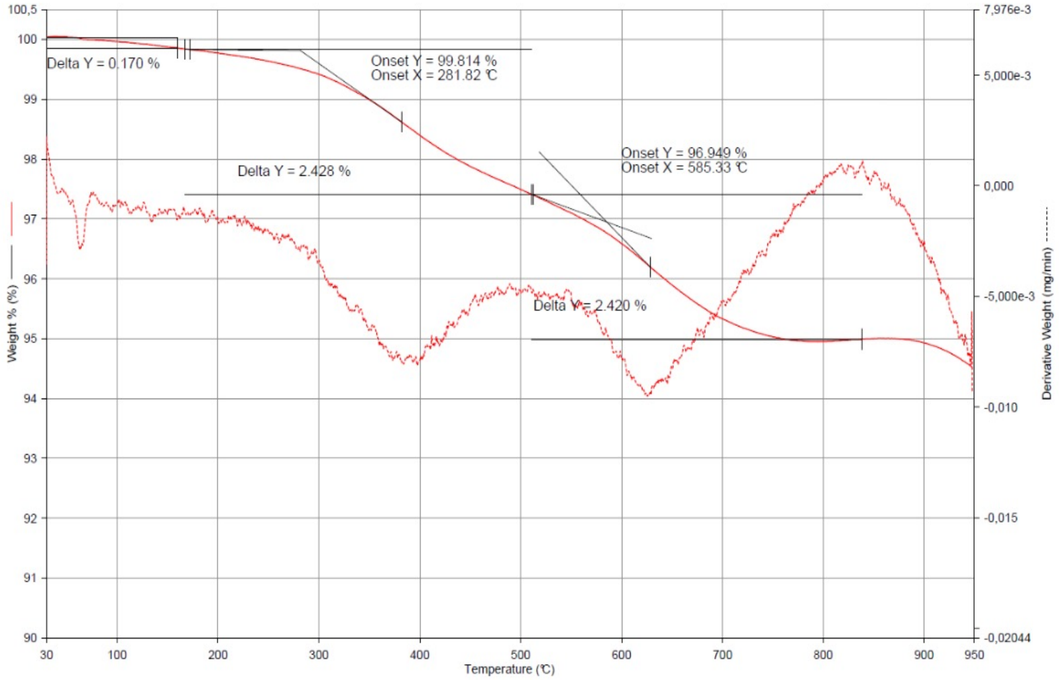
Polysil Alu is a specific coating which, allows to obtain polished surfaces (colored or not) on aluminum or magnesium alloy components, fully avoiding the need of paint preparation steps and galvanic baths. **NALUCOAT process** was designed for making environmentally sustainable and recyclable aluminum components with multiple advantages:

- Lightness: the coating thickness of about 20 microns does not impact the weight of the part.
- Touch effect: unlike polymeric paints, the good thermal conductivity coupled with the low thickness allows the feeling of touching a metal part to be maintained.
- Anti-fingerprint: the coating does not imprint and remains glossy
- Polysil's transparency is UV stable and does not yellow (although some pigments may have color variations)
- Abrasion resistance (*better than PVD coatings*)
- Corrosion resistance: superior to most anti-corrosion treatments
- Compliance with the MOCA (Food)
- Resistance to high temperatures
- Laserable (*allows the laser to be used for marking without altering the surface*)



Polysil Thermal Shield

Thanks to the use of proper inorganic additives combined with the unique properties of Polysil, a coating with very low thermal conductivity was developed**: Polysil Thermal Shield.**
Thermal conductivity measures suggest having reached **0.050 W/mK** (to be confirmed since it was obtained on thin coating, for which there are no reliable measure methods).
What is for sure is that the excellent mechanical and thermal resistance properties of Polysil Thermal Shield coating, enabled it to pass gas dynamic strength tests at Mack 3.9.
Thermal shock tests at 800°C (on ceramic specimens) were also successfully passed.



Nanoprom has developed **Polysil TSR** (Thermal Shield Resin), a resin based on amorphous silica, which offers excellent resistance to high temperatures and fire (interesting flexural strength after fire exposure also thanks to low thermal conductivity) and can be combined with Carbon-fibers or Quartz-fibers, to produce, **fireproof structural Composites.**

Thermogravimetric analysis of Polysil_TSR indicates that the resin undergoes limited mass reduction (5%) upon heating up to 700°C, while in the range 700°C-1000°C the mass remains substantially stable.

Polysil Thermal Shield Blanket

Thermal Shield Blanket can be used as a high temperature resistant material for thermal protection of mechanical parts or as fire protection of load-bearing structures in construction.

Important fields of application for this product are the automotive industry and the energy industry (engines and turbines). It can be used on industrial ovens or industrial machines in general, or as an insulator for battery packs, and generally for any application that needs a material that can thermally insulate and is resistant to direct flame.

There are two types of Thermal Shield Blanket (Standard and Plus) with different performances:

- Thermal Shield Blanket Standard - Preliminary data show stability at 900°C for about 5 minutes, with a temperature reduction of 60% in a thickness of 4 mm.
- Thermal Shield Blanket Plus - Stable at 1200°C for 10 minutes, with a temperature reduction of 75%.

Thermal conductivity at average temperature:

- @ 200°C ~ 0,045 W/mK
- @ 400°C ~ 0,075 W/mK
- @ 650°C ~ 0,105 W/mK

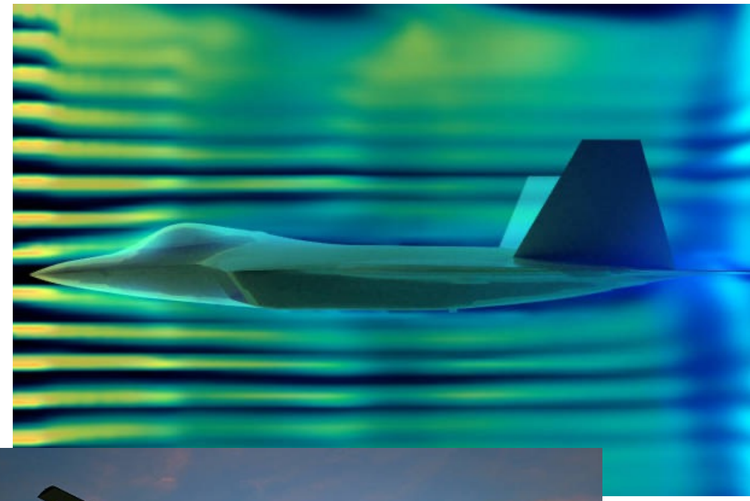
Aerodynamics drag reduction

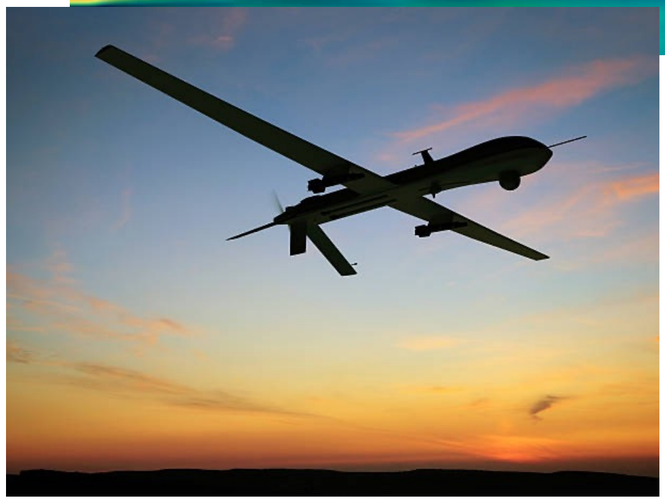
Friction drag is created in the boundary layer due to the viscosity of the air and the resulting friction against the aerodynamic surface. When the laminar flow breaks away from the surface, turbulent flow is created, which creates more drag. The aerodynamic drag can be reduced by moving the zone at which the laminar flow becomes turbulent. Thanks to the low surface tension of the Polysil coatings, the friction developed by the air (which is due, in part, to the adhesion of moisture on the surface) is greatly reduced by stabilizing the laminar flow on the aerodynamic surface.

Wind tunnel tests on F1 car up to 300 Km/h, have demonstrated that Polysil coating allows an average reduction of Cx (drag coefficient) of about 0.9% (thanks to the low surface tension and a surface roughness of Ra 0.025).

Tank tests also showed a reduction in hydrodynamic drag of up to 17% in the 0-50 knot range.

The wide temperature range resistance (-70°C to 800°C) and its excellent corrosion protection make Polysil the best coating for subsonic aircraft to reduce fuel consumption and leading-edge icing reduction, as well as for supersonic vehicles and missile systems to reduce surface heat generation.





Polysil Feature Matrix

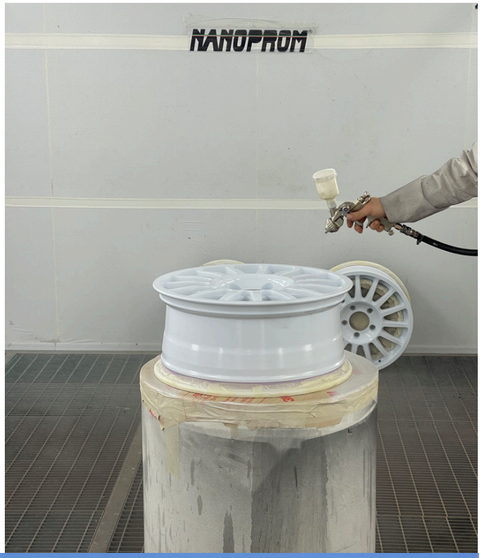
Feature	Polysil SC Polysil SCC Polysil SCC+	Polysil HT	Polysil Inorganic	Polysil Thermal	Polysil Graphene	Polysil Nalucoat	Polysil Thermal Shield (coating and resin)
Sol gel process	✓	✓	✓	✓	✓	✓	✓
Typical thickness	5-15 µm	10-25 µm	2-5 µm	10-20 µm	5-20 µm	10-25 µm	5-20 µm
Temp. range	-70°C - 400°C	-70°C - 400°C	-70°C - 800°C	-70°C - 400°C	-70°C - 400°C	-70°C - 200°C	-70°C - 920°C
Max. temp (Short time)	500°C	500°C	920°C	500°C	500°C	300°C	Over 1600°C
Non-flammable Coating	✓	✓	✓	✓	✓	✓	✓
Fire protection for substrate	✗	✗	✗	✗	✗	✗	✓
Oxidation protection for additive manufacturing parts (as built) and carbon/carbon parts	✓	✓	✓	✗	✗	✓	✗
Oxidation protection, Chemical protection	✓	✓	✓	✓	✓	✓	✓
Compliance with the MOCA (Food)	✓	✓	✓	✓	✗	✓	✗
Passing the outgassing test	---	---	✓	✓	---	---	---
UV stable	✓	✓	✓	✓	✓	✓	✓
Enhanced heat exchange	---	---	---	✓	✓	✓	✗
Lightweight coating (from 25 g/m^2 coating + top coat)	✓	✓	✓	✓	✓	✓	✓

Aerospace Polysil Application Matrix

Application Area	Polysil SC Polysil SCC Polysil SCC+	Polysil HT	Polysil Inorganic	Polysil Thermal	Polysil Graphene	Polysil Nalucoat	Polysil Thermal Shield (coating and resin)
Satellite			✓	✓	✓		
Fuselage	✓	✓	✓				✓
Wing	✓	✓	✓				✓
Electric Motor				✓	✓		
Electronic chassis				✓	✓		
Fire resistant chassis		✓	✓				✓
Fireproof bulkheads							✓
Interior	✓					✓	
Additive manufacturing parts	✓	✓	✓				
Mechanical parts	✓	✓	✓	✓			
Hydrogen and oxygen tanks			✓		✓		
Fuel tanks	✓	✓	✓				
Exhaust			✓				✓
Stealth Coatings					✓		
Heat exchangers			✓	✓	✓		
Galvanic corrosion protection	✓	✓	✓	✓			✓

Productivity

The use of Polysil according to product specifications makes it highly effective in coating surfaces. The application process of Polysil involves the application of 2 coats of paint (wet-on-wet) with the final application of the top-coat also wet-on-wet. This allows for efficient production processes, eliminating the intermediate curing times required by conventional paints.
In addition, with a suitably smooth base coat, no primer application is required.



Polysil high coverage efficiency allows it to cover about 25sqm with one liter of product; using an electrostatic spraygun can cover about 60sqm, this coverage efficiency makes Polysil further eco friendly compared to traditional paints.

NANOPROM

ITALIAN QUALITY

RETE ALTA TECNOLOGIA
EMILIA-ROMAGNA
HIGH TECHNOLOGY NETWORK

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