Nano-Coatings for Surface Protection

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Good coatings are applied to various structures and vehicles, usually at the place of manufacture. These coatings may deteriorate with time, and recoating may be necessary to ensure continued operation. Nano-coatings, which comprise nanoparticles of inorganic silicon incorporated into a water-based polymer solution, can be sprayed onto a coated structure to preserve it from environmental degradation. This article describes nanotechnology and explains how these coatings are made and how they function.

High-quality, long-lasting coatings are applied to various structures and vehicles at the factory. These finishes are applied in a controlled environment, using quality materials and highly specialized application equipment. The metal is clean and in good condition before coating. The longer the original factory coating lasts, the higher its value to the asset and the owner.

Finish quality and durability are also important to customers. For this reason, many manufacturers go to great lengths to prevent conditions that cause new coatings to fail prematurely. This involves critical surface preparation, rust inhibitive pretreatment, and state-of-the-art paint systems. The integrity of the original application allows responsible owners to provide a significant increase in coating life through proactive maintenance.

Nano-coatings have been developed as surface protectants to enhance the appearance and increase the durability of factory finishes and industrial coatings just as wax protects an automotive finish. Permanon† is one of the first commercially available surface protectant coatings to incorporate nanotechnology into its formulation. The main component of nano-coatings is inorganic silicon, basically a highly compounded component of glass. When inorganic silicon is processed into nanosize particles and incorporated into a water-based polymer solution, it is transformed into a highly effective, ultra-thin coating for virtually any hard surface.

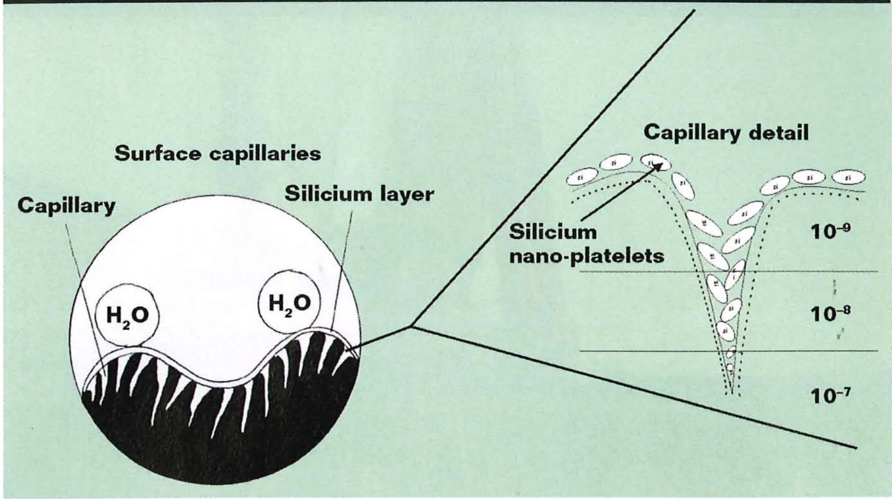
Nanotechnology

Nanotechnology is the creation, organization, or manipulation of materials, devices, or systems at the nanometer (one billionth of a meter) level. For comparison, a pin head 1 mm in diameter is equal to 1 million nm. Nano-coatings are applied at a thickness of 100 nm.

†Trade name.

When nano-coatings are applied to a clean surface, that surface takes on properties that are virtually identical to hardened glass. The coating is chemically inert and will not react with the base material. Dirt will not bond to the treated surface, reducing soiling and organic staining. Acid rain and other chemical compounds easily wash off, significantly reducing the hydroscopic nature of surfaces exposed to industrial or environmental pollution.

FIGURE 1

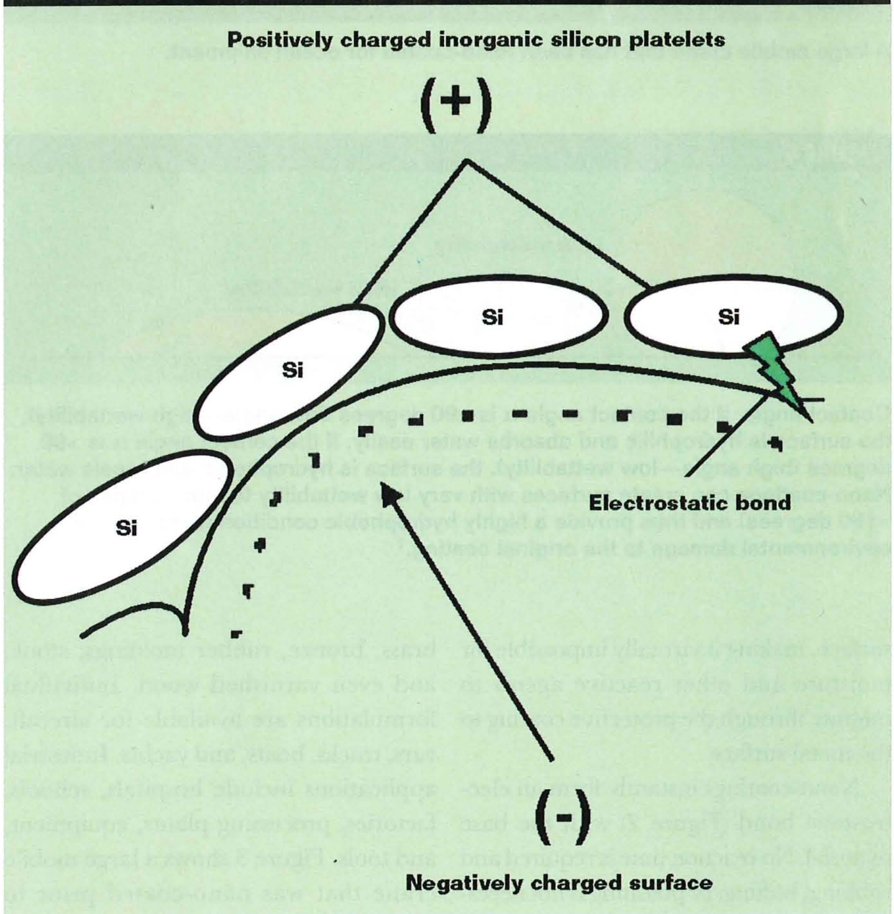


Nano-coatings closely follow the contour of the capillaries. High contact angles (Figure 4) create the hydrophobic qualities of the coating.

Capabilities of Nano-Coatings

- Dirt cannot bond to treated surfaces.
- Surfaces are protected against industrial and environmental pollution.
- Airborne dust is repelled.
- The need for harsh and potentially dangerous chemical cleaners is eliminated.
- Cleaning costs are reduced by 50% or more.
- The clarity of transparent materials is improved.
- Surfaces are resistant to temperature extremes—from 40 to 300 °C.
- Surfaces are resistant to ultraviolet (UV) exposure (undiluted provides 100% UV protection).
- Surfaces have antifouling properties.
- "Maintainability" of coated surfaces is significantly improved.

FIGURE 2



Nano-coatings form an electrostatic bond to the base material.

Function of Nano-Coatings

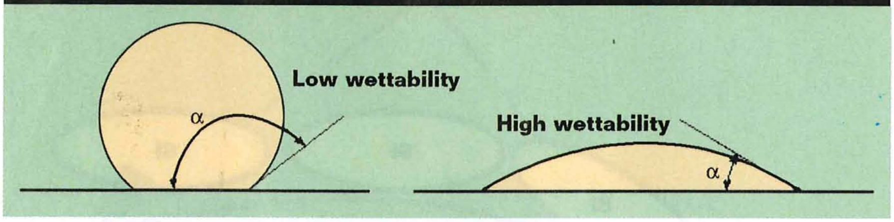
All materials are porous and contain microscopic peaks and valleys. These irregularities are known as capillary structures. On manufactured surfaces (including paints and coatings), there may be millions of these defects per square inch. Contaminants such as fine dirt, minerals, and pollutants are drawn into the voids where they are extremely hard to remove. Capillary structures also provide microbes and bacteria with a place to grow and multiply.

The silicon particles are laminar shaped. This means they overlap each other like the scales of a fish. These platelets are deposited on the capillary wall, closely follow the contour of its surface, and fill up to 90% of the capillary voids, thus providing a surface that is smooth and more resistant to soiling (Figure 1). The overlapping of the platelets also reduces the permeability of the treated

FIGURE 3

A large mobile crane that has been nano-coated for ocean shipment.

FIGURE 4



Contact angle. If the contact angle α is <90 degrees (low angle—high wettability), the surface is hydrophilic and absorbs water easily. If the contact angle α is >90 degrees (high angle—low wettability), the surface is hydrophobic and repels water. Nano-coatings can create surfaces with very low wettability (contact angles of >160 degrees) and thus provide a highly hydrophobic condition that prevents environmental damage to the original coating.[2]

surface, making it virtually impossible for moisture and other reactive agents to migrate through the protective coating to the metal surface.

Nano-coatings instantly form an electrostatic bond (Figure 2) with the base material. No reaction time is required and rubbing, buffing, or polishing is not necessary. As soon as the silicon particles come in contact with the surface, the bonding process is complete.

Nano-coatings can be applied to any clean, hard, manufactured surface including painted steel, fiberglass, aluminum, stainless steel, galvanized metal, brass, bronze, rubber moldings, stone, and even varnished wood. Individual formulations are available for aircraft, cars, trucks, boats, and yachts. Industrial applications include hospitals, schools, factories, processing plants, equipment, and tools. Figure 3 shows a large mobile crane that was nano-coated prior to ocean shipment.

Water Repellency

The filling of the capillary structures with silicon nanoparticles produces a hydrophobic surface. A hydrophobic surface is one that repels moisture. In contrast, a hydrophilic surface is one that absorbs moisture. The potential of a surface to absorb or repel moisture is based on many factors including temperature, relative humidity, material homogeneity, and static electricity. Surface condition is also a major factor—the rougher the surface, the higher the spreading rate or attraction for water. The smoother the surface, the more repellant it is to moisture.

Contact Angle

Nano-coatings provide a simple way to determine surface protection. The formation of large, closely spaced water droplets demonstrates that moisture is effectively prevented from being absorbed into the surface profile. The classification of water droplets on a hard surface is known in industry as a water break test (ASTM F22-02[1]).This test is used extensively in industry to check surface cleanliness. The size, shape, and height of the water droplets are measured by their contact angle. Contact angle is figured by a straight line that starts at the base of the droplet and travels along its outer surface to the break off point. The measurement between this line and the surface determines contact angle.

The contact angle (Figure 4) determines the hydrophobic quality of the coating. A contact angle of 0 degrees indicates that moisture has completely wetted the surface. No water droplets have been formed. A contact angle of 100 degrees indicates that the surface has poor wetting properties and the size of the water droplets is small in relation to the surface. When the contact angle exceeds 150 degrees, this is considered a super-hydrophobic surface and the surface is highly repellent to water.

When the contact angle reaches 160 degrees, this is rated as an ultra-hydrophobic surface. This indicates that the surface is extremely repellent to moisture. There are very few incidences of surfaces that exceed a contact angle of 160 or more. In nature, bird feathers and the lotus leaf are examples of ultra-hydrophobic surfaces. Figures 5 and 6 illustrate surfaces having high contact angles.

Application

Nano-coatings can be applied by spray, brush, wiping, sponge, or immersion. Since the coating is only 100-nm thick (less than the diameter of a human hair), care must be taken to avoid over-application to prevent waste. For example, when the coating is applied by atomized air spray, a 0.05- to 0.12-mm or larger spray tip is used depending on the coating manufacturer's recommendations. After application, the surface is wiped down with a microfiber cloth or rinsed with demineralized water to prevent water spots.

A surface free from grime, dust, and oil residue is all that is required before application. Since the coating is applied at only 100-nm thick, 1 L has the potential to cover >1,000 ft^2 (93 m^2) of surface area.

One application of a nano-coating can last up to one year. Annual coating reapplication can extend service life indefinitely. During reapplication, the silicon particles will seek out damage point locations, rebond, and restore full performance capabilities. The electrostatic bonding of the inorganic silicon nanoparticles makes a nano-coating the only type of protective coating with the ability to reduce corrosion activity without the build up of excessive film thickness.

Conclusions

Nano-coatings, like wax on an automotive finish, protect the primary coated surface from environmental degradation. For many applications, nano-coatings offer a simple and environmentally safe way to extend coating life through a program of surface preservation and proactive maintenance.

FIGURE 5

Water droplets on a metal surface exhibiting high contact angles.

FIGURE 6

Water droplets on a concrete surface exhibiting high contact angles.

References

1 ASTM F22-02, "Standard Test Method for Hydrophobic Surface Films by the Water-Break Test" (West Conshohocken, PA: ASTM International, 2007).

2 G. Carboni, "Experiments on Surface Phenomena and Colloids," March 2002, translation ed. G.L. Stuart, Figure 10, http://www.funsci.com/fun3_en/exper2/exper2.htm (June 14, 2011).

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