

Surfaces Matter

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ABSTRACT

Aculon, Inc. specializes in inventing and commercializing unique molecular-scale surface and interfacial coatings leveraging nanotechnology discoveries made at Princeton University. These coatings can be classified into three functional areas; non-stick, pro-stick/adhesion, and anti-corrosion.

The company has formulated coating solutions and processes for numerous markets including optical, display, electronics, consumer products and industrial coatings. These specialized coatings outperform all known alternatives in characteristics such as adhesion, stain resistance, and scratch resistance.

Fueling the company's commercialization efforts are its proprietary Self-Assembled Monolayer of Phosphonates (SAMP) technology. The commercialization of SAMP treatments can be used for a variety of applications including imparting hydrophobicity, adhesion, or corrosion inhibition to numerous substrates.

For surface treatments to be effective, they must be mechanically and chemically stable under conditions experienced in the intended area of use. Aculon's proprietary Self-Assembled Monolayer of Phosphonates methodology can impart any of these properties as desired to metals, metal oxides and even some polymer surfaces by drawing on its library of structurally tailored phosphonic acids.

The secret to the commercialization is covalent bonding, which creates a uniquely strong attachment between the SAMP and the substrate. Because the SAMP is one approximately 1.5 nm thick, it completely covers the material to which it is applied, and assures total surface coverage regardless of the type or texture of that material. The composition of the SAMP determines the properties that it imparts to its substrate.

In 1998, Professor Jeffery Schwartz of Princeton University discovered that well-ordered monolayers of phosphonates could be formed by self-assembly on a wide variety of oxide and oxide-terminated surfaces. At that time Professor Schwartz and his team also discovered that a simple dip process enabled SAMP formation on substrates of complex structures and geometries, as well as traditionally "unreactive" surfaces.

The research showed that SAMP adhesion to oxides was mechanically strong and resisted removal by hydrolysis and oxidation. It showed further that by using the dip method, SAMPs of

a variety of molecular structures, including aliphatic, aromatic, and heteroaromatic, could be prepared.

Commercialization of SAMPs proves that such surface-bound phosphonates can dictate control of the surface properties of myriad substrates and that they can be implemented using well-known industrial techniques and conditions. These processes can be scaled to meet the needs of large or small facilities, and can be applied to surfaces of nearly any size or shape without special needs. Based on the needs of the producer, surface modification can be completed during the time of manufacturing or can be performed as a post-production step.

INTRODUCTION

Aculon commercializes unique surface and interfacial coating materials that leverage nanotechnology discoveries made at Princeton University and at Aculon. These coatings can be classified into three functional areas:

Non-stick coatings (nano-scale “Teflon”)
Pro-stick/adhesion coatings (nano-scale “Velcro”)
Anti-oxidation coating

Aculon has formulated coating solutions and processes for numerous markets including optical, display, electronics, consumer products, and industrial coatings.

THEORY

Aculon’s proprietary “self-assembled monolayer of phosphonates (SAMP)” methodology can coat surfaces to impart hydrophobicity, adhesion, or corrosion inhibition.

DISCUSSION

A monolayer is a nanoscale coating that is one molecule thick or 1-4 nanometers in thickness ($1\text{nm} = 1 \times 10^{-9}$ meters). A phosphonate is a phosphorous acid that combines a reactive phosphonic acid or “reactive head group” and a carbon based tail group connected through a stable phosphorous carbon bond (P-C). The reactive “heads” react with the surface through strong and stable metal phosphorous bonds, and the tails stick out from the surface and are chosen for their chemical functionality (non-stick, pro-stick, etc.). The SAMP is covalently bound to the substrate surface. This permanent chemical bond is highly stable under ambient conditions.

SAMPs can coat metals, metal oxides, glass, ceramics, particles, semiconductors, and even some polymer surfaces by drawing on its library of structurally tailored phosphonic acids.

What are the key benefits of the technology?

- **Functional Effects.** Aculon’s surface and interfacial treatments can transform ordinary materials into “next-generation” products by imparting designed properties on the nanoscale. Aculon’s treatments can add functionality such as adhesion or repellency on many different polymers or materials

- Permanence and robustness: Aculon's surface treatments are covalently bound to the substrate surface. This permanent chemical bond is highly stable under ambient conditions. Stronger and more durable than existing coating chemistries
- Nanoscale treatment. Due to its nanometer scale, Aculon's surface treatment does not interfere with desired mechanical surface features that may be critical to the function or appearance. The treatment does not change the texture or appearance of the surface in any way
- Economical use of materials (approx. 1 nmol/cm²), and easy to apply through wet coating methods such as dip-coating, spraying, printing, gravure rods, and stamping.
- Platform Technology: Broad range of substrates can be coated (metals, semiconductors, glass, ceramics, polymers)
- Non-leaching. Aculon's surface treatment does not leach from its material host so there is no undesirable secondary result
- Safety: Pre-clinical studies have shown no adverse effects whatsoever from the surface treatment.

How is the technology applied?

- Easy-to apply using existing industrial processes and by the consumer (ex. sprayed, dipped, ink-jet printing, roll coating/gravure rod, stamping)
- Solution based (either aqueous or solvent), *vacuum deposition can be used in some cases if required

SUBSTANCES

Metals - Aculon's non-stick coatings (nano-scale "Teflon"), pro-stick/adhesion coatings (nano-scale "Velcro"), and anti-oxidation coatings can be used on a broad range of metals.

Tin
Titanium
Copper
Invar
Tantalum
Gold
Silicon
Tungsten
Silver
Zinc
Stainless Steel
Palladium
Nickel
Chrome
Indium
Aluminum

Polymers - Aculon's surface and interfacial treatments can transform ordinary polymers into "next-generation" products by imparting designed properties on the nanoscale. Aculon's treatments can add functionality such as adhesion or repellency on many different polymers such as:

- Nylon
- Polyamides
- ABS
- Kevlar
- Polycarbonate
- Bismaleimide Triazine
- Aramid
- Oxide-Reinforced Polymers
- FR4
- Polyimides
- Polysiloxanes
- SU8
- Polyesters

Glass/Ceramics – Aculon’s treatments can add functionality such as adhesion or repellency on many different glass and ceramic surfaces.

- Window Glass
- Borosilicate Glass
- Porcelain
- Tile
- Marble
- Granite
- Brick
- Mortar
- Mirrors

Particles – Aculon’s surface and interfacial treatments can disperse nanoscale to microscale particles.

- Silica
- Titania
- Yttria
- Copper
- Tantalum
- Gold
- Silver
- Zinc
- Palladium
- Nickel
- Aluminum

Semiconductors – Aculon’s non-stick coatings (nano-scale “Teflon”), pro-stick/adhesion coatings (nano-scale “Velcro”), and anti-corrosion coatings can be used on a broad range of semiconductors. These semiconductors include:

- Silicon
- Gallium Arsenide
- Cadmium Sulfide

Aluminum Nitride
Germanium
Organic Semiconductors

Fabrics/Other – Aculon’s non-stick coatings (nano-scale “Teflon”) can be used on a broad range of fabrics:

Cotton
Wool
Polyester
Denim
Rayon

MARKETS

Optical:

Aculon’s nanoscale Teflon technology creates a water-repellant (hydrophobic) and oil-repellant (oleophobic) surfaces to repel water, dust, oil, and dirt on optics. Coated sunglasses or prescription eyewear have significant improvement of their smudge repellency, and smudge removability. Glasses stay cleaner longer, and the coating helps make cleaning easy, resulting in clearer vision and easier maintenance.

Two products commercialized using Aculon’s technology are the Oakley Hydrophobic and Hilco, Inc Shield products.

Display:

OEM and Consumer applied coatings have been developed for electronic displays. Cell phones, PDA, iPod, iPhone, laptops, and touch screens can be coated with Aculon’s permanent nanoscale easy-clean coating can be applied by the OEM on both glass and plastic screens. In addition, a temporary coating can be applied by the consumer using a felt-tip applicator.

Electronics:

Aculon’s non-stick coatings and pro-stick/adhesion coatings, and anti-oxidation coatings can be used on a broad range of materials used in electronic applications as interfacial treatments of dissimilar materials are particularly important for performance and reliability in electronics. Applications include adhesion of low dielectric resins to copper for printed circuit boards and chip scale packaging, potential replacement of silver in conductive epoxies and printing conductive inks with anti oxidation treated copper, and superior bonding of both die attach adhesives and epoxy molding compounds to numerous types of leadframe materials.

Industrial & Consumer:

Cleaning stainless steel surfaces is a laborious exercise, as fingerprints and smudges are often smeared rather than readily removed, and fingerprints often leave so-called ghost stains from localized oxidation reactions. Other consumer applications include: jewelry cleaners, wheel cleaner, fabric, and fishing flies.

Nanoparticles:

Aculon has exclusively licensed patented technology from Princeton University for coating oxide surfaces, including metal oxide and yttria nanoparticles. This technology, along with other surface modification techniques, coating methods and materials developed at Aculon, serve as a platform on which nanoparticle surfaces can be tailored for a broad range of uses.

CONCLUSIONS

Surfaces play an important role in many applications including optical, display, electronics, industrial, consumer, and nanoparticles. Aculon's development of materials and processes involving Self-Assembled Monolayer of Phosphonates (SAMPs) has led to a new coatings platform with broad ranging capabilities for new functionally and enhanced chemical bonding.

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