NANOCOATINGS

CONSTRUCTION & EXTERIOR PROTECTION

APPLICATIONS
Anti-fingerprint, anti-bacterial, conductive, ice-repellent and many more.

COMPANIES
All the leading companies profiled.

MARKETS
End user markets and products.

MATERIALS
Nanomaterials used in coatings.

EDITION 3
APRIL 2014
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Executive Summary

Nanotechnology is a key driver for new and innovative coating applications and nanocoatings have shown substantial growth in recent years. The nanocoatings industry is conservatively estimated to be $2 billion in 2012, growing to over $6.8 billion in 2020. In the coating sector, high transparency, new functionalities and high-quality performance are increasingly important requirements. The key element that nanostructured coatings provide however is protection from ice, pollutant, UV, fire, heat, bacteria, marine life, touch and corrosion. These factors cost global industry billions in maintenance, loss and downtime each year and can pose a significant public health hazard. For example, direct corrosion costs account for 3-4% of a country’s GDP worldwide.

Exceptional properties
Thin films, nanoscale coatings and nanostructured surfaces are widely applied in different industry sectors and provide prime examples of how nanotechnology can improve or disrupt the existing technology sectors or create new ones. Nanocoatings display significant performance advantages over traditional coatings as well as being more cost-effective in the medium- to long-term. Properties such as anti-microbialism, product longevity, thermal insulation, gloss retention, dirt and water repellency, hardness, corrosion resistance, flame retardancy, ultraviolet radiation stability, improved energy efficiency, anti-graffiti, self-cleaning, moisture absorbing, gloss retention and chemical and mechanical properties are improved significantly using nanostructured materials.

Global revenues
The global coatings market is estimated at over $95 billion in 2012. Global commercial and manufacturing institutions are turning to nanocoating technologies to further enhance current commercial products or add completely new properties to existing technology. Automotive, construction, polymer, solar, glass, oil and gas organizations understand that nanocomposite-based coatings offer significant product performance and cost-saving advantages.

Asian market growing
The market will be driven by increased demand in the Asian and developing countries markets. The Chinese market is growing rapidly and photocatalytic TiO2 nanoparticles for self-cleaning and deodorizing effect are in strong demand in the rest of Asia. These coatings represent a $900 million plus market in Japan alone. There is strong government support for nanotechnology in these regions and a large number of multi-nationals and innovative companies developing products and processes based on nanoparticles.

Main markets
Main markets for nanostructured
coatings are:
• Medical (Short term disposables and Long-term reusables.
• Food manufacturing.
• Textiles/ leather.
• Marine Coatings.
• Water treatment.
• Electronics.
• Household care.
• Construction.
• Automotive/ Transport.
• Tools & Engineering.
• Energy.

Nanocoatings in construction and exterior protection
Nanomaterials are particularly suited to protecting the surface of various construction materials such as glass, concrete, sand limestone or marble from environmental influences like water staining, moss, algae as well as soot and oil stains; and also function as corrosion inhibitors for reinforced steel. Paints and surface coatings are commercially available that create a low energy facing thus rendering a building surface highly hydro- and oleophobic, thereby helping to prolong maintenance cycles and reduce cleaning. Dirt repellent protective paints and photocatalytic coatings are the most prominent applications in the construction and exterior protection industry. Dirt collection (accumulation) in building exteriors poses considerable problems for building maintenance. Cleaning such building surfaces is generally done by using detergents accompanied with scrubbing, wiping and high-pressure water jets. These processes have several shortcomings such as use of chemical detergents, high consumption of energy and labour cost. This naturally leads to high maintenance costs; therefore, an effective self-cleaning coating is desirable.
A number of large multinations, including Evonik Degussa, Dupont, Schott, 3M and Corning produce anti-fouling and easy-to-clean coatings for a variety of markets.
In recent years, self-cleaning coatings using photocatalytic Titanium Dioxide (TiO2) have gained considerable industry attention. With assistance of little UV light from fluorescence source or sunlight, TiO2 offers two unique properties: (a) strong oxidation power, and (b) super-hydrophilicity. Strong oxidation power can be used to kill bacteria attached on the wall, or oxidize/remove foul smells from stains in toilets (e.g., TiO2-coated tile and TiO2-coated glass are commercially available). Super-hydrophilic properties allow dirt and stains to be easily washed away with water or by rainfall when such a coating is applied to exterior surfaces. Nanoparticle TiO2 self-cleaning coating greatly benefit building maintenance, especially for skyscrapers, as they reduce the need for costly surface cleaning. Photocatalyst coatings are also used to improve indoor air quality by reducing the amount of volatile organic compound and other toxic chemicals people are exposed to in hotels, restaurants, commercial business facilities, university laboratories, hospitals and residences. Anti-stick properties of nanocoatings leads to less staining and easy-cleaning-effect on exterior and interior surfaces. Anti-graffiti properties mean that stubborn stains such as graffiti, which in the past called for intensive cleaning efforts can be washed away simply with a high pressure hose. Water-based, VOC-free, clear impregnating nanoparticle wood coatings containing nanoscale UV absorbers have been commercialised. They are designed for use on masonry and concrete surfaces, provides superior water repellency, reduces efflorescence, and provides significantly improved abrasion resistance.
Table 1: Global market for nanocoatings 2012-2020

<table>
<thead>
<tr>
<th>Nanocoating</th>
<th>Total global market 2012 (Conservative estimates)</th>
<th>Nanocoating % penetration 2012</th>
<th>Nanocoatings market 2012</th>
<th>Total global market 2020</th>
<th>Nanocoating % penetration 2020</th>
<th>Nanocoating market 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-fingerprint</td>
<td>$85 million</td>
<td>12%</td>
<td>$10.2 million</td>
<td>$213 million</td>
<td>65%</td>
<td>$138 million</td>
</tr>
<tr>
<td>Anti-microbial</td>
<td>$6.5 billion</td>
<td>5.5%</td>
<td>$357 million</td>
<td>$8.7 billion</td>
<td>13.5%</td>
<td>$1.17 billion</td>
</tr>
<tr>
<td>Conductive</td>
<td>$2.5 billion*</td>
<td>2.5%</td>
<td>$62.5 million</td>
<td>$4 billion</td>
<td>22.5%</td>
<td>$900 million</td>
</tr>
<tr>
<td>Anti-corrosion</td>
<td>$3 billion</td>
<td>1.9%</td>
<td>$57 million</td>
<td>$6.2 billion</td>
<td>7.5</td>
<td>$465 million</td>
</tr>
<tr>
<td>Abrasion and wear resistant</td>
<td>$5 billion**</td>
<td>1.1%</td>
<td>$55 million</td>
<td>$7.6 billion</td>
<td>5.5%</td>
<td>$418 million</td>
</tr>
<tr>
<td>Self-cleaning (Bionic)</td>
<td>$145 million</td>
<td>100%</td>
<td>$145 million</td>
<td>$550 million</td>
<td>100%</td>
<td>$550 million</td>
</tr>
<tr>
<td>Self-cleaning (Photo-catalytic)</td>
<td>$1.2 billion***</td>
<td>100%</td>
<td>$1.2 million</td>
<td>$2.2 billion</td>
<td>100%</td>
<td>$2.2 billion</td>
</tr>
<tr>
<td>UV-resistant</td>
<td>$365 million</td>
<td>3.5%</td>
<td>$12.7 million</td>
<td>$535 million</td>
<td>9%</td>
<td>$48 million</td>
</tr>
<tr>
<td>Anti-icing</td>
<td>$200 million</td>
<td>14%</td>
<td>$28 million</td>
<td>$320 million</td>
<td>35%</td>
<td>$112 million</td>
</tr>
<tr>
<td>Thermal barrier/ flame retardant</td>
<td>$4 billion</td>
<td>1%</td>
<td>$40 million</td>
<td>$7.6 billion</td>
<td>3.5%</td>
<td>$266 million</td>
</tr>
<tr>
<td>Anti-fouling/easy to clean</td>
<td>$2.5 billion</td>
<td>4%</td>
<td>$100 million</td>
<td>$4.4 billion</td>
<td>13%</td>
<td>$572 million</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$25.49 billion</td>
<td>-</td>
<td>$2.06 billion</td>
<td>$42.3 billion</td>
<td>-</td>
<td>$6.84 billion</td>
</tr>
</tbody>
</table>

* Some reports put this market as high as $8 billion.
** Estimates for this market vary from $4.5 billion to $13 billion
*** The Japanese market is estimated to be over $1 billion alone in 2012, with Asia and Europe comprising the rest of the market.
The report covers the main nanostructured coatings suppliers and application developers. The market is also forecasted from 2012 through to 2020. End user markets and applications are also outlined. The research methodology initially encompassed a comprehensive and exhaustive search of the literature on nanostructured coatings. Secondary sources included journals and related books, trade literature, marketing literature, technology roadmaps, other product/promotional literature, annual reports, analyst reports, conference proceedings and other publications. An extensive patent analysis was conducted to gauge technological innovation and to determine research activity as it applies to new product development.

A series of interviews were conducted via email and phone with nanotechnology and nanomaterials company representatives, academics, technology suppliers, technical experts, trade association officials, and consulting companies. In addition, service providers and end users were contacted to evaluate current and future demands.

The market was then quantified for relevant application impact and the main prerequisites for commercial success were identified including performance of the technology, supplier distribution, legislation, pricing of competing products, sale of complementary products, industry environment and demographics of the customer.

Market revenues were forecast based on current revenues generated by companies marketing nanocoated products, market penetrations in key end user markets of these products and future estimated growth in these markets.
Introduction

Nanostructured coatings offer great potential for various applications due to their superior characteristics that are not typically found in conventional coatings. They are now routinely applied to a wide variety of substrate materials (plastics, glass, metals, ceramics and textiles). Nanoscale characterisation is drawing increasing interest from manufacturers and regulators with the former concerned about achieving the desired performance at appropriate cost and the latter concerned about toxicological impact. Interest in nanostructured materials for coatings is due to their remarkable mechanical, electrical, magnetic and optical properties and the possibilities of synthesizing materials with unique physical–chemical properties. Highly sophisticated surface related properties, such as optical, magnetic, electronic, catalytic, mechanical, tribological, chemical as well as magnetic, electronic and optical can be obtained by advanced nanostructured coatings, making them attractive for many modern industrial applications.

Definition

Nanomaterials are manufactured with at least one dimension less than 100 nm. Nanocoatings are two-dimensional materials that can be produced by physical (e.g. plasma, PVD), chemical (e.g. CVD, sol-gel) and particulate (e.g. TiO2) technologies. Nanocoatings can be categorized as nanocrystalline, multilayer coatings with individual layer thickness of nanometres, and nanocomposites. In nanocoating systems the uppermost layer is a clear coating (ranging between 5–50 μm in thickness), which, for example, not only protects the underlying layers or substrate from chemical and UV degradation, but also provides protection from mechanical damage that can result in surface blemishes/scratches. Design of nanostructured coatings requires consideration of numerous factors, e.g. the interface volume, crystallite size, single layer thickness, surface and interfacial, energy, texture, epitaxial stress and strain, etc., all of which depend significantly on materials selection, deposition methods, processing parameters and what is especially important, service condition of coated parts. The size and size distribution of nanoparticles in a coating formulation has a large influence on its functional characteristics.

Properties

Due to the properties inherent at the nanoscale, nanostructured coatings are typically multifunctional, exhibiting one or combinations of the following properties: scratch and abrasion resistance, anti-static, oleophobic, easy-to-clean, anti-reflective, anti-microbial activity, sensor and catalytic activity. They are mainly used for the prevention of soiling (incrustation/clogging; protein adhesion/cell adhesion; biofilm formation); aging/degradation; and friction/wear.
Advantages of nanocoatings include:
• Better surface appearance
• Good chemical resistance
• Decrease in permeability to corrosive environment and hence better corrosion properties
• Optical clarity
• Increase in modulus and thermal stability
• Easy to clean surface
• Anti-skid, anti-fogging, anti-fouling and anti-graffiti properties
• Better thermal and electrical conductivity
• Better retention of gloss and other mechanical properties like scratch resistance.
• Anti-reflective in nature
• Chromate and lead free
• Good adherence on different type of materials.

Nanoparticles
The exploitation of the novel properties afforded by nanoparticles in coatings and paints is a relatively recent development. Nanoparticles allow for novel products such as:
• Easy-to-clean coatings
• Effect coatings
• Antibacterial coatings
• Scratch-resistant coatings
• Photocatalytic coatings
• Paints with UV protection
• Wall coatings as screens against high-frequency electromagnetic radiation
• Switchable coatings
• Electro-conductive coatings
• Self-healing coatings
• Nano-primers for anti-corrosive coatings and paints
• Heat-insulating coatings.

Nanoparticles used in the coatings industry include:
• Titanium dioxide
• Silicon dioxide
• Iron oxide
• Zinc oxide
• Silver.

Titanium dioxide has photocatalytic properties. For this reason, titanium dioxide in nanoscale form is found in wall paints for removing organic pollutants from ambient air. Nanostructured silicon dioxide mainly serves as a rheological additive; it is also used in self-cleaning wall paints. UV protection in transparent coatings is the most important application for iron oxide and nanoscale zinc oxide. Silver in nano-form is a constituent of wall paints for hospitals and food processing operations, in order to prevent attack by bacteria and other microorganisms.

Particle size, surface area and electronic properties are three key properties that nanoparticles desirable for a variety of industrial applications. The large specific surface areas of nanoparticles allow them to have enhanced reactivity, superior absorption, higher solubility, lower melting point and enhanced electronic properties, such as quantum effects found on particles with particle size < 10 nm (important for electronic and optoelectronic applications). Because of the salient features of nanoparticles, advanced products and coatings can be produced by embedding nanocomposites into polymer matrices.

Nanoparticles are invisible to the human eye; when embedded in a polymer matrix. They do not affect visible light transmission, making them ideal materials for advanced clear coats. When nanoparticles are dispersed in polymer to form advanced transparent nanocomposites, they offer improvements in coating strength, thermal and scratch resistance, solar absorption and reflectance (window coatings) and improve performance of photochromic coatings and automotive clear coatings. Polymer nanocomposite coatings embody properties with incredible practical applications for mechanical, optical and electronic products.

No sacrifice in light transmission in optical applications
In general, improving the mechanical properties of a polymer coat (such as scratch resistance) involves the optimization of the polymer lacquer components and reinforcement of the structure of the coat using microscopic fillers. When using nanopowders (size < 100 nm) as fillers to reinforce polymers, their higher interfacial surface area makes the nanofiller behave differently than common fillers; with the nanocomposite requiring very low loading of nanomaterial to yield significant improvement in mechanical and other desired properties. These properties are enhanced without sacrificing visible light transmission. This is critical for optical applications. Where glass coatings are concerned, spectrally selective coatings made of nanoparticles is a hot topic. Nanoparticles offer greater spectral control than other materials by offering market-leading transparency and clarity. For spectrally selective solar control films, high transparency in the visible light spectrum with absorption and reflection of infrared light are key criteria being considered.
Commercial window films can gain competitive advantage by embedding nanoparticles into plastic films later applied to glass surfaces. Nano films offer heat absorption and reflective properties while maintaining fairly high levels of transparency.

Production methods
With the advent of vacuum-based physical vapor deposition technologies, methods such as sputtering and pulse laser deposition have become the primary tools in nanomaterial R&D (although they were originally discovered and produced by solution chemical methods). However, there is a new drive to bring transparent ceramic oxide processing back to chemical solution deposition.

Production methods include:
• Electrospray and electrospinning: Reactants are passed through a fine nozzle, which is subject to a high voltage, causing the reactants to form charged droplets or fibers that are collected on a grounded collector. Such processes can be used to coat large surfaces.
• Gas phase synthesis (chemical and physical vapor deposition, CVD and PVD, plasma and laser ablation): The material is vaporized by intense heat (e.g. laser) and then deposited on a substrate (usually under vacuum). This is generally expensive, difficult to scale-up and not suitable for temperature-sensitive materials (e.g. polymers, biomolecules).
• Self-assembly: Reactants combine in a predefined manner to form a layer on the desired substrate.
• Sol-gel processes: Reactants are mixed under defined temperatures and pressures to produce colloids of nanoparticles. Major issues include strictly defining particle size distribution (or porosity), preventing particle agglomeration, and the amount of waste material produced.

Solution-based approaches to nanoparticle-polymer composite deposition are more cost effective than ultra-high vacuum physical processes, allowing a thick layer of nanomaterial to be deposited in a single step. General coating approaches involve dip coating, doctor blade coating, metering rod coating, slot-casting, spray-coating, screen printing and inject printing. All these approaches use nanoparticle-polymer dispersion to cast a nanocomposite polymer onto suitable substrates.

A key challenge to this approach is the inherently poor dispersability of specific nanomaterial. Although, there are numerous commercially available nano powders in the market, aggregate contained in those products makes their processing very challenging as they can directly affect performance as well as transparency. The ability to achieve polymer nano-dispersion amenable to current liquid-based coating processes will usher in an era of nanocoating supremacy over traditional industrial coating products with smarter, stronger, more durable, cost-effective coating materials.

Most of the current nanotechnology coating solutions for repelling stains and preventing scratches on a variety of surfaces are first generation nanotechnology solutions. There are deposited so they are electro-statically or at best ionically bonded to the surfaces they are deposited on. This means that the repelling ability of many first-generation nanocoated fabrics degrades rapidly with washing or use and very few can pass normal abrasion testing. The new, second-generation nanocoatings are covalently bonded.
Anti-corrosion nanocoatings

Table 2: Market summary anti-corrosion nanocoatings

<table>
<thead>
<tr>
<th>Main markets</th>
<th>Oil &amp; gas, marine, military</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total market 2012</td>
<td>$3 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>1.5%</td>
</tr>
<tr>
<td>CAGR to 2020</td>
<td>9.5%</td>
</tr>
<tr>
<td>Total market 2020</td>
<td>$6.2 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>7.5%</td>
</tr>
<tr>
<td>Nanocoatings market 2020</td>
<td>$ 465 million</td>
</tr>
</tbody>
</table>

Corrosion is a significant problem for owners of industrial equipment, installations, and plants. As it is a slow process it can change, assuming many forms and arising very rapidly since it is triggered by environmental factors, such as oxygen and water, which cannot be eliminated. It is possible, however, to prevent corrosion, and nanocoatings are important as they can shift the focus of the problem from the protection against corrosion to its prevention.

Market drivers
Main market drivers are as follows:
• constantly increasing requirements on the performance of anti-corrosion coatings
• rising cost awareness
• increasing environmental attention related to the reduction of solvent content
• growing application of surface tolerant protective coatings systems or coatings providing universal adhesion
• replacement of toxic inhibitors such as hexavalent chromium

The presence of corrosive chemicals and harsh operating and environmental conditions can result in structural failure or loss of containment, which can be costly in terms of repairs, lost or contaminated products, environmental damage, and potential risk to personnel. Corrosion factor is very costly and has a major impact on the economies of industrial nations companies. The annual direct cost of metallic corrosion in U.S. economy is estimated $300 billion and € 200 billion in Europe. While there is an increasing need for more effective and less costly products, EU and government regulations are also driving demand for lower content of chemicals in coatings. Therefore need for new solutions is urgent.

Nanoparticles
Protective coatings incorporating nanoparticles have been developed as industrial protective coatings, corrosion protection coatings, thermal resistant, fire retardant coatings, water based anti-corrosion coatings and fire retardant polymers. Nanocoatings can significantly increase the cost/benefit ratio, providing cost effective solutions and improved performances. Nanoparticles such as nano silica, clay, ZnO, Fe2O3 and TiO2 are typically used in organic coatings for improving corrosion resistance. These nanomaterials have a very high surface area. When this surface is functionalized, it can deliver high loadings of organic corrosion inhibitors. Thus, tailored nanoparticles are the perfect carrier for delivery of the needed level of active corrosion inhibitors. Nanomaterials engineering also extend the possibility of engineering ‘smart’ coatings that can release corrosion inhibitors on demand when the coating is breached, stressed or an electrical or mechanical control signal is applied to the coating.

Applications
Nanocoatings can be designed to be used on any steel substrate and could thus be applied to components from a wide range of markets. These markets include mining (ore processing, surface and underground mining, and drilling), utilities (seals, accessories, and bearings), defense, agriculture (tillage and planting), construction (drill bits, grinder hammer tips, and other hardware), shipping, energy (wind power at sea) and transportation (brakes, valve trains, bearings, and gears).
Table 3: Anti-corrosion nanocoatings-Principles, Properties, Effect, Applications and Companies

<table>
<thead>
<tr>
<th>Principle</th>
<th></th>
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<tbody>
<tr>
<td>• Nanoparticle materials have a very high surface area. When this surface is functionalized, it can deliver high loadings of organic corrosion inhibitors. Thus, tailored nanoparticles are the perfect carrier for delivery of the needed level of active corrosion inhibitors.</td>
<td></td>
</tr>
<tr>
<td>• Nanostructured materials engineering extends the possibility of engineering ‘smart’ coatings that can release corrosion inhibitors on demand when the coating is breached, stressed or an electrical or mechanical control signal is applied to the coating. Inherently conducting polymer (ICP) films containing inhibiting anions as the dopant anions can release them when the film is coupled to a breach in the coating. Research has developed chrome-free corrosion inhibiting additives in which organic corrosion inhibitors are anchored to nanoparticles with high surface areas that can be released on-demand.</td>
<td></td>
</tr>
<tr>
<td>• Incorporation of nanoparticles in the hybrid sol–gel systems increases the corrosion protection properties due to lower porosity and lower cracking potential. Incorporation of inorganic nanoparticles can be a way to insert corrosion inhibitors, preparing inhibitor nanoreservoirs for self-repairing pre-treatments with controlled release properties.</td>
<td></td>
</tr>
<tr>
<td>• Nanostructures form protective oxidation scales with superior adhesion to the substrate. The high density of grain boundaries provides fast diffusion paths, promoting selective oxidation of protective oxide scales. The fine-grained coatings and/or the fine-grained oxide scales show a fast creep rate at high temperatures, which can release the stresses accumulated in the scales, therefore reducing the scale spallation tendency. The oxides formed on nanocrystalline coatings are micro pegged onto the grain boundaries to form a complex interface that results in better scale adhesion to the metal substrate. Nanocrystalline alloy coatings, oxide-dispersive alloy coatings and metal-oxide composite coatings show superior high-temperature corrosion resistance</td>
<td></td>
</tr>
<tr>
<td>Properties</td>
<td></td>
</tr>
<tr>
<td>Nanoparticles have:</td>
<td></td>
</tr>
<tr>
<td>• High surface areas (e.g. good carriers)</td>
<td></td>
</tr>
<tr>
<td>• Novel surface chemistries (triggered release)</td>
<td></td>
</tr>
<tr>
<td>• Multiple property enhancements (e.g. corrosion resistance and chemical resistance to Skydral)</td>
<td></td>
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<table>
<thead>
<tr>
<th>Effect</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>• Protect organics from reacting with resin due cure</td>
<td></td>
</tr>
<tr>
<td>• Prevents leach-out</td>
<td></td>
</tr>
<tr>
<td>• Triggered release possible due to novel surface chemistries</td>
<td></td>
</tr>
<tr>
<td>• Nano-sized silica has proved to be an alternative to phosphate–chromate pretreatment that is hazardous due to toxic hexavalent chromium</td>
<td></td>
</tr>
<tr>
<td>• Nano cobalt–phosphorus is compatible with most existing electroplating equipment and positioned as an effective replacement for the hexavalent chromium</td>
<td></td>
</tr>
<tr>
<td>• Nanocomposite coatings based on hydroxyapatite nanoparticles can provide better corrosion protection of titanium that can be utilized for fabrication of advanced biomedical implants</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Anti-corrosion nanocoatings - Principles, Properties, Effect, Applications and Companies

<table>
<thead>
<tr>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Corrosion resistance is essential for metals used in a wide range of applications. Sectors that require the use of anticorrosive coatings include: Oil and Gas, Shipping and Shipyard sector, Energy, Infrastructures, Rolling Stock, Lifting equipment, Port machinery and the Lighting sector</td>
</tr>
<tr>
<td>• Current naval ships utilize a protective coating system that consists of separate primer and topcoat films, both individually applied. This practice contributes significantly to the ship's construction schedule and cost. The affordability of the coating process could be improved if a one-coat, direct-to-metal coating could be used instead.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>• AnCatt</td>
</tr>
<tr>
<td>• Millidyne Oy</td>
</tr>
<tr>
<td>• NanoHorizons Inc.</td>
</tr>
<tr>
<td>• Nano Hygiene Coatings Ltd</td>
</tr>
<tr>
<td>• PChem Associates, Inc.</td>
</tr>
<tr>
<td>• Sarastro GmbH</td>
</tr>
<tr>
<td>• Surfactis</td>
</tr>
<tr>
<td>• Xtalic</td>
</tr>
</tbody>
</table>
Abrasion and wear-resistant nanocoatings

Table 4: Market summary for abrasion and wear-resistant nanocoatings

<table>
<thead>
<tr>
<th>Main markets</th>
<th>Automotive, aerospace and aviation, tools, manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total market 2012</td>
<td>$5 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>1.1%</td>
</tr>
<tr>
<td>CAGR to 2020</td>
<td>5.37%</td>
</tr>
<tr>
<td>Total market 2020</td>
<td>$7.6 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>5.5</td>
</tr>
<tr>
<td>Nanocoatings market 2020</td>
<td>$418 million</td>
</tr>
</tbody>
</table>

By engineering composite materials at the nanoscale it is possible to obtain super hard materials that rival diamond in performance. In machining and wear resistant applications, hard coatings are essential for enhancing the wear resistance and toughness properties of cutting tools. Conventional coatings do not meet the needs of current machining and manufacturing requirements as well as nanostructured coatings.

Nanoparticles
Surface hardness and the wear resistance of materials can be significantly improved through a nanoparticulate coating making the base material harder and improving the wear resistance of the surface. Nanoparticles improve wear resistance and toughness properties and offer comprehensive corrosion inhibition as well as meeting stringent regulatory and safety requirements. Research is very active and significant progress has been achieved. There are already many commercial applications in mechanical structures and in the machining of materials. The emphasis is on metal treatment, but also promising results have been shown for non-metallic materials. Nanoscale structuring using nano size grains and nanolayers helps in preventing/pinning dislocations, thereby dramatically enhancing wear-resistance properties. Nanocoatings also significantly improve other properties such as toughness and thermal shock resistance of the intended surface for a variety of conventional materials such as ceramics, composites and metal alloys. Nanocoatings display a lower wear rate than their counterparts of commercial coarse-grained powders. This improvement in wear resistance is attributed to the high hardness and toughness of the nanomaterials, and the change of fracture and material-removal due to ultrafine particle size. Nanoscale multilayer coatings, which consist of alternating layers of materials, further improve the performance of single-layer nanostructured coatings. When properly tailored, nano-multilayer coatings produce super hardness and super modulus effects.

Markets
Target markets are friction management, machine and engine technology are especially large targets of developmental activity. The metal finishing market is estimated to be $32 billion. Application targets are heavily worn items such as floors, stairs, handrails, safety goggles, visors and dental fillers. There is also great commercial potential in engines and devices. The potential market for such coatings and coated articles is very wide range from large scale steel, Ni and Ti alloys sheet products to cutting and processing tools; wear resistant parts for automotive, aircraft/space and chemical industries; biocompatible and wear resistant surgical implants down to miniature parts for electronics and microelectronics, including MEMS.
### Table 5: Abrasion and Wear-Resistant Nanocoatings - Principles, Properties, Effect, Applications and Companies

<table>
<thead>
<tr>
<th>Principle</th>
<th>Abrasion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Inorganic based nanoparticles provide improved scratch and abrasion resistance, by increasing alumina or silica content. High concentration is responsible for the improved scratch and wear resistance of the coating.</td>
</tr>
<tr>
<td></td>
<td>Wear</td>
</tr>
<tr>
<td></td>
<td>• By engineering composite materials at the nanometer scale it is possible to obtain super hard materials that rival diamond in performance. In machining and wear resistant applications, hard coatings are essential for enhancing the wear resistance and toughness properties of cutting tools. Conventional coatings do not meet the needs of current machining and manufacturing requirements as well as nanocoatings</td>
</tr>
<tr>
<td></td>
<td>• Nanoscale structuring using nano size grains and nanolayers helps in preventing/pinning dislocations, thereby dramatically enhancing wear-resistance properties. Nanocoatings also significantly improve other properties such as toughness and thermal shock resistance of the intended surface for a variety of conventional materials such as ceramics, composites and metal alloys</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties</th>
<th>Abrasion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Scratch resistance of coating can be improved by using micron sized inorganic fillers, but they cause matt or semi-matt appearance to coating by scattering visible light. However, by using nanoparticles, scattering of light can be reduced significantly. Nano powders of particle size around 40 to 60 nm are effective fillers. Nanoparticles such as ZrO2, AlOOH, SiO2 have been embedded in UV-curable lacquers, resulting in improved abrasion resistance</td>
</tr>
<tr>
<td></td>
<td>• Protective layers based on polymeric or particulate sols applied onto a surface as a sol by simple mechanical coating techniques such as dip and spin coating. The resulting protective layers are purely inorganic, transparent and curable or sinterable even at a low temperature and have a high microhardness in addition to a very good corrosion protection effect. Storage modulus and temperature resistance are increased</td>
</tr>
<tr>
<td></td>
<td>• Highly reactive as they cure in seconds, easy to apply as no special equipment is needed, are environmentally friendly because they contain no solvents, and because of the small particle size, are transparent.</td>
</tr>
</tbody>
</table>

| Wear       |
|------------|----------|
|           | • Outstanding wear, abrasion and erosion resistance |
|           | • Unique flexibility, toughness and impact-resistance |

<table>
<thead>
<tr>
<th>Effect</th>
<th>Abrasion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ceramic network gives hardness to the coatings and organic components make coatings more flexible and tough</td>
</tr>
<tr>
<td></td>
<td>• The materials are resistant to a large number of chemicals.</td>
</tr>
<tr>
<td></td>
<td>• Nanoparticles have been shown to improve the mechanical properties even at low loadings and due to their small particle size; they do not affect the transparency of clear coats. Scratch resistance also improved further due to homogeneous distribution of nanoparticles in polymers. Even a small amount can retain the appearance of surface without any negative impact on coating and its gloss</td>
</tr>
<tr>
<td></td>
<td>Wear</td>
</tr>
<tr>
<td></td>
<td>• Nanocrystalline metals or coatings display a lower wear rate than their counterparts of commercial coarse-grained powders. This improvement in wear resistance is attributed</td>
</tr>
</tbody>
</table>
to the high hardness and toughness of the nanostructured materials, and the change of
fracture and material-removal due to ultrafine particle size.
- Nanoscale multilayer coatings, which consist of alternating layers of materials, further
improve the performance of single-layer nanocoatings. When properly tailored, nano-multilayer coatings produce superhardness and supermodulus effects.

Applications

Abrasion
- Vehicle and protective environments. Scratch-resistant varnishes for automobile paint
- Light metals (Aluminium and Magnesium) and various kinds of steel, such as technical parts for cars and aircrafts as well as engine parts and production areas for food technology.
- Mar and scratch resistant coatings for furniture and parquet, scratch resistant high gloss lacquers on wood and barrier coatings on plastics.
- Protective layers for semiconductor chips
- Transparent plastics such as acrylic glass (PMMA), SAN and polycarbonate, e.g. for plastic walls or displays of mobile phones.
- Anti-corrosion coatings for pipelines

Wear
- Steel coatings: Wear on steel components leads to both direct and indirect costs and energy losses, including losses due to plant inefficiencies and down-time for repairs. The cost of wear to the U.S. economy was estimated to be $20 billion annually in 1978, equivalent to $65 billion dollars annually today
- Nanocoatings can be designed to be used on any steel substrate and could thus be applied to components from a wide range of markets. These markets include mining (ore processing, surface and underground mining, and drilling), utilities (seals, accessories, and bearings), defense, agriculture (tillage and planting), construction (drill bits, grinder hammer tips, and other hardware), and transportation (brakes, valve trains, bearings, and gears).
- Aerospace parts

Companies

- BYK-Chemie
- Mitsubishi Carbide
- Advanced Thin Film, Inc.
- Cleancorp Nanocoatings
- CMR Coatings
- DAW Caparol
- Industrial Nanotech, Inc.
- Industrial Science and Technology Network (ISTN, Inc.)
- Inframat Corp.
- Integran Technologies
- Modumetal, Inc.
- Nanofilm
- Nanogate Coating Systems GmbH
- Nanosol AG
- The NanoSteel Co.
- Nanovere Technologies, Inc.
- NANO-X GmbH
- NTC Nanotech Coatings GmbH
- Perpetual Technologies
- Resodyn Corporation
- TDA Research
Anti-fouling/easy to clean nanocoatings

Table 6: Market summary for anti-fouling and easy to clean nanocoatings

<table>
<thead>
<tr>
<th>Main markets</th>
<th>Construction, marine, household, sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total market 2012</td>
<td>$2.5 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>4%</td>
</tr>
<tr>
<td>CAGR to 2020</td>
<td>7.3%</td>
</tr>
<tr>
<td>Total market 2020</td>
<td>$4.4 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>13%</td>
</tr>
<tr>
<td>Nanocoatings market 2020</td>
<td>$572 million</td>
</tr>
</tbody>
</table>

Anti-fouling and easy to clean nanocoatings have gained impressive market traction, especially in the building materials, marine and household (mainly bathroom) sectors. These coatings allow for improvement in the appearance of machinery and equipment, hygiene and corrosion resistance in different environments. Applications are in:
- Machinery and equipment operating in dirty process conditions.
- Energy technology equipment; wind generators, solar cells and solar collectors.
- Sensors
- Packaging
- Home appliances.

Application targets are generally all surfaces for which contaminants harm the aesthetic, hygienic or technical operation. The goal is both a better level of cleanliness as well as a reduction of cleaning costs.

Nanoparticles

Coatings incorporating nanoparticles and nano layers have been developed more durable, easy-to-clean paints and anti-graffiti coating for buildings and structures. Nanoparticulate coatings can make the applied surface both hydrophobic and oleophobic at the same time, which have been used on anti-graffiti surfaces. Anti-graffiti coatings have been developed in the last few years that include the use of polysiloxane modified polyurethanes whose weathering resistance is increased by adding silica nanoparticles.

Markets

A number of large multinationals, including Evonik, Dupont, Schott, 3M and Corning produce anti-fouling and easy-to-clean coatings for a variety of markets. Other companies in this and self-cleaning markets include Ferro, United Protective Technologies, Masco, PPG, AGC and Raytheon.

Commercial examples of easy-clean coatings include construction materials such as painted metals for increased durability (predicted lifetime of 5-7 years), plastic materials (e.g. polycarbonate, PMMA) with increased transparency and dirt resistance (easy-to-clean surface hinders the dirt pick-up by the substrate, resulting in cleaner surfaces that are easier to clean) and surfaces in kitchens and bathrooms.

The marine sector a main market for anti-fouling nanocoatings. Marine fouling is estimated to cost the shipping industry over 200 billion dollars per year. Anti-fouling nanocoatings are also being applied in the food processing industry. Heat exchangers are widely used in industries such as brewing, dairy and food processing. A problem for these heat exchangers is fouling due to the adhesion of both organic and inorganic materials on the steel walls. This results in reduced thermal transfer efficiency and increased energy costs. Fouling in heat exchangers and associated pipes in the dairy sector reduce performance and increase costs, as well as causing potential contamination problems. By applying anti-fouling nanocoatings it is possible to reduce downtime and cut cleaning costs.

According to G-Shield, the costs of removing and repairing graffiti damage are estimated at $12 - $25 billion annually. Graffiti is a major, increasing danger to architectural heritage materials. Graffiti can affect to all class of surfaces materials and in the majority of the cases, the cleaning is very expensive and quite often, the penetration into the pores contained in the substrate material induces an irreparable effect onto the painted surface.
Anti-graffiti paint has been developed by functionalising nanoparticles and polymers to form a coating repellent to water and oil at the same time. As a result, the coated surface is non-stick and very easy to clean, and able to withstand repeated graffiti attacks. Nanostructured coatings represent the latest application area for anti-graffiti coatings by making the surface highly hydrophobic independently on its nature and protecting it against water, minimizes the adhesion of the graffiti paint and facilitates the removing process with water, soft detergents or hand cleaning by employing a cloth.

Table 7: Anti-fouling and easy to clean nanocoatings—Principles, Properties, Effect, Applications and Companies

| Principle | • Minimization of free surface energy by chemical nanotechnology  
• Self organizing anti-adhesion groups |
|---|---|
| Properties | • Suited for metal, glass, ceramic, stone and plastic surfaces  
• Simple application e.g. by spraying and room temperature or thermal curing  
• Transparent, good adhesion on the substrate without difficult pretreatment  
• Low free surface energy: < 24 mN/m² contact angle about 60° against hexadecane  
• Anti-stick- and easy-to-clean-properties, additionally with corrosion protection (for metals)  
• Durable, inert surface protection with good mechanical and chemical stability, for plastic materials: scratch and abrasion resistance comparable with mineral glass possible  
• Additionally anti-bacterial (bioizide) properties or protection against moss-, fungus and alga growth possible |
| Effect | • Durable hydro and oleophobicity, meaning water and organic liquids pearl off easily  
• Anti-stick properties: leading to less staining and easy-cleaning-effect  
• Anti-graffiti properties mean that stubborn stains such as graffiti, which in the past called for intensive cleaning efforts can be washed away simply with a high pressure hose  
• Nanocoatings inhibit the adhesion of microbes and marine fouling organisms. Establishment of nanostructure results in appreciable reduction in interaction between germs and surface. Nano-coating helps in reduction of germs, virus, algae by oligodynamic effect of metal component. |
| Advantages | • Water and soil repellent; can be graffiti repellent  
• Easy to clean (but cleaning of dust still needed)  
• Invisible  
• Several types commercially available  
• Fairly durable |
| Disadvantages | • Easily mechanically damaged  
• Sometimes vulnerable to sunlight  
• Not always easy to repair  
• Not all types applicable on existing surfaces  
• Care must be taken to apply the coating correctly  
• Needs (regular and even) water source  
• Oil and oily dirt as well as surfactants stick to the surface very well.  
• If droplets contain dirt and remain on the glass, a punctiform soiling will result.  
• Sometimes dust attraction because of electrostatic charge.  
• Weak or no bonding between coating material and glass: short durability.  
• Sanitary equipment: tiles, bath tubs, shower bath, wash basin, armature made of stainless steel and chromium, shower cabinets, toilet seat, bath room furniture |
<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building protection and the construction industry: Anti-graffiti, facades,</td>
<td>• Building protection and the construction industry: Anti-graffiti, facades, windows, doors, gates, distributor box</td>
</tr>
<tr>
<td>windows, doors, gates, distributor box</td>
<td>• Kitchen and domestic articles: kitchen utensils, baking oven, pots and frying pans</td>
</tr>
<tr>
<td>• Kitchen and domestic articles: kitchen utensils, baking oven, pots and frying</td>
<td>• Industrial beverage and food production: kneader, stirrer, containers.</td>
</tr>
<tr>
<td>pans</td>
<td></td>
</tr>
<tr>
<td>Industrial beverage and food production: kneader, stirrer, containers.</td>
<td></td>
</tr>
<tr>
<td>Applications</td>
<td></td>
</tr>
<tr>
<td>• Garden, leisure and sport utensils: garden-furniture, lawn-mower, boats,</td>
<td>• Garden, leisure and sport utensils: garden-furniture, lawn-mower, boats, outdoor-lamps</td>
</tr>
<tr>
<td>outdoor-lamps</td>
<td>• Automobiles: head lights, windows, felloe, varnish as well as vehicle industry in general: construction machines, tractors, military and camping vehicles</td>
</tr>
<tr>
<td>• Marine: Wetted surfaces of naval vessels coated with nanomaterial approximately</td>
<td>• Marine: Wetted surfaces of naval vessels coated with nanomaterial approximately five years ago still show virtually no signs of biofouling. In addition, this nanocomposite material has superior bond strength, toughness, wear resistance, corrosion resistance and ductility compared to conventional coatings. Also, the material is very environmentally friendly, as it does not contain copper, lead or other heavy metals that are hazardous to the marine environment.</td>
</tr>
<tr>
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<td></td>
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<tr>
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<tr>
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<tr>
<td>toughness, wear resistance, corrosion resistance and ductility compared to</td>
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<tr>
<td>conventional coatings. Also, the material is very environmentally friendly,</td>
<td></td>
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<tr>
<td>as it does not contain copper, lead or other heavy metals that are hazardous</td>
<td></td>
</tr>
<tr>
<td>to the marine environment.</td>
<td></td>
</tr>
<tr>
<td>Companies</td>
<td>Companies</td>
</tr>
<tr>
<td>• Aculon</td>
<td>• Aculon</td>
</tr>
<tr>
<td>• Akzo Nobel</td>
<td>• Akzo Nobel</td>
</tr>
<tr>
<td>• Bühler AG</td>
<td>• Bühler AG</td>
</tr>
<tr>
<td>• Chamelic Ltd</td>
<td>• Chamelic Ltd</td>
</tr>
<tr>
<td>• Clariant Produkte (Deutschland) GmbH</td>
<td>• Clariant Produkte (Deutschland) GmbH</td>
</tr>
<tr>
<td>• Cotec GmbH</td>
<td>• Cotec GmbH</td>
</tr>
<tr>
<td>• De Cie GmbH</td>
<td>• De Cie GmbH</td>
</tr>
<tr>
<td>• Diamon-Fusion International, Inc.</td>
<td>• Diamon-Fusion International, Inc.</td>
</tr>
<tr>
<td>• Evonik Degussa</td>
<td>• Evonik Degussa</td>
</tr>
<tr>
<td>• GXC Coatings</td>
<td>• GXC Coatings</td>
</tr>
<tr>
<td>• Hempel</td>
<td>• Hempel</td>
</tr>
<tr>
<td>• Inframat</td>
<td>• Inframat</td>
</tr>
<tr>
<td>• LANCAS</td>
<td>• LANCAS</td>
</tr>
<tr>
<td>• Millidyne Oy</td>
<td>• Millidyne Oy</td>
</tr>
<tr>
<td>• NanoCare AG</td>
<td>• NanoCare AG</td>
</tr>
<tr>
<td>• Nanocyl</td>
<td>• Nanocyl</td>
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<tr>
<td>• Nanogate Coating Systems GmbH</td>
<td>• Nanogate Coating Systems GmbH</td>
</tr>
<tr>
<td>• Nanolabs Corp.</td>
<td>• Nanolabs Corp.</td>
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<tr>
<td>• Nanophos SA</td>
<td>• Nanophos SA</td>
</tr>
<tr>
<td>• Nanopool GmbH</td>
<td>• Nanopool GmbH</td>
</tr>
<tr>
<td>• Nanosol AG</td>
<td>• Nanosol AG</td>
</tr>
<tr>
<td>• Nanovations Pty Ltd</td>
<td>• Nanovations Pty Ltd</td>
</tr>
<tr>
<td>• NANO-X GmbH</td>
<td>• NANO-X GmbH</td>
</tr>
<tr>
<td>• Nano Hygiene Coatings Ltd</td>
<td>• Nano Hygiene Coatings Ltd</td>
</tr>
<tr>
<td>• n-tec GmbH</td>
<td>• n-tec GmbH</td>
</tr>
<tr>
<td>• NTC Nanotech Coatings GmbH</td>
<td>• NTC Nanotech Coatings GmbH</td>
</tr>
<tr>
<td>• Percenta AG</td>
<td>• Percenta AG</td>
</tr>
<tr>
<td>• Rittal GmbH</td>
<td>• Rittal GmbH</td>
</tr>
</tbody>
</table>
Self-cleaning (Bionic) nanocoatings

Table 8: Market summary for self-cleaning (bionic) nanocoatings

<table>
<thead>
<tr>
<th>Main markets</th>
<th>Glass, hygiene, household, plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total market 2012</td>
<td>$145 million</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>100%</td>
</tr>
<tr>
<td>CAGR to 2020</td>
<td>18.1%</td>
</tr>
<tr>
<td>Total market 2020</td>
<td>$550 million</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>100%</td>
</tr>
<tr>
<td>Nanocoatings market 2020</td>
<td>$550 million</td>
</tr>
</tbody>
</table>

Manufacturers are greatly interested in implementing technology that can keep their products looking clean and new after years of use. Ideally, these coatings will be durable and allow greatly prolonged cleaning cycles such that products would need only occasional rinsing with water or wiping with a damp cloth to remove dirt and oils. Applications include virtually any outdoor surface that requires occasional cleaning. A number of existing technologies minimize cleaning, but typically lack durability. Therefore manufacturers are seeking to exploit nanocoatings that both minimize cleaning and are durable enough to last a number of years when exposed to environmental conditions such as sand, dirt, oil, pH, wind, ice, moisture, salt, sun, pollution, bird droppings and tree sap.

Nanoparticles

Clean or self-cleaning surfaces can be achieved by two principally different approaches. A photocatalytic coating can be applied to the surface, where the effect of the sun’s ultraviolet rays catalytically breaks down organic dirt. At the same time the surface changes into a superhydrophilic at which time the water spreads evenly over the surface and less drying traces are formed by dripping. Another way to manufacture a self-cleaning (bionic) surface is done in accordance with the Lotus effect phenomenon in which the surface becomes a super-hydrophobic. A superhydrophobic surface can be achieved when hydrophobic chemistry is combined with a suitable surface roughness. A superhydrophobic surface is able to repel water droplets completely; such surfaces exhibit water droplet advancing contact angles (CA) of 150º or higher.

Markets

Superhydrophobic coatings and films have a wide spectrum of applications; they are used not only for resisting water and fog condensation, but also for preventing contamination. Markets include:

- Architectural glass
- Building materials
- Auto glass
- Shower doors
- Consumer electronics
- Solar panel glass covers
- Traffic signs/signals
- Greenhouses
- Displays
- Military/Defence
- Aerospace
- Industrial, sports and military protective eyewear
- Optical components and sensors.

A number of companies have developed products seeking to replicate the lotus effect (BASF, Evonik). However there are a number of disadvantages to this technology that have reduced its widespread uptake. There are questions over durability, requirements for expensive lithography and resultant scalability to large surface areas. Consumer applied hydrophobic coatings for plastics currently on the market include Raincoat (MotoSolutions), Visor Proof (Nikwax), and Oakley Hydrophobic Coating (Oakley). However, none of these are superhydrophobic, resulting in only modest improvements in water contact angle. Liquipel, Aridion, and NeverWet and H2O (Samsung) have been developed for application in consumer electronics (smart phone waterproof coatings).
Table 9: Self-cleaning (Bionic) nanocoatings—Principles, Properties, Applications and Companies

| Principle | • Minimization of free surface energy by chemical nanotechnology  
• Self organizing anti-adhesion groups on nanostructured surface |
|-----------|------------------------------------------------------------------|
| Properties | • Suited for metal, glass, ceramic, stone and plastic surfaces  
• Simple application e.g. by spraying and subsequent thermal treatment  
• Translucent (metal, ceramic, glass, stone) or transparent (plastic, e.g. Polycarbonate)  
• Good adhesion on the substrate without difficult pretreatment  
• Low free surfaces energy: <24mN/m²  
• Contact angle >120 (water), superhydrophobic  
• Self-cleaning effect, if the nanostructured low free energy surface is exposed to rain fall |
| Effect | • Water nearly pearls off completely  
• Leaned dirt is rinsed off easily by (rain-)water |
| Advantages | • Water and soil repellent  
• Self cleaning (if wetted by rain or other method)  
• Invisible  
• Several types commercially available |
| Disadvantages | • Not very durable  
• Easily mechanically damaged  
• Not always easy to repair  
• Not all types applicable on existing surfaces  
• Metal surfaces hard to treat with most systems  
• Care must be taken to apply the coating correctly  
• Needs (regular and even) rain or other water source  
• Detergents destroy the effect  
• Coating is visible in most cases (translucent, not transparent).  
• Surfactants adhere very well and can block the effect even permanently.  
• Coating is removed by and by – porous surface remains and is much harder to clean than an uncoated surface.  
• No “self-repair-effect”  
• Coating cannot be repaired on site. |
| Applications | • Outdoor surfaces, which are exposed to the elements such as self-cleaning facades (concrete-, plastic, metal or painted surfaces), windows, doors and gates;  
• Solar plants, wind turbines (rotor blades, housing), satellite bowls.  
• Windows  
• Car screen windows and mirrors  
• Clothes  
• Road signs |
| Companies | • CleanCorp Nanocoatings  
• CTC Nanotechnology  
• CVD Technologies Limited  
• Cytonix Corporation  
• Gelwell Biotech Corp  
• GXC Coatings  
• Luna Innovations  
• Microphase Coatings, Inc. |
Table 9: Self-cleaning (Bionic) nanocoatings—Principles, Properties, Applications and Companies

<table>
<thead>
<tr>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>• NanoCover A/S</td>
</tr>
<tr>
<td>• Nanoproofed</td>
</tr>
<tr>
<td>• Nanovere Technologies, Inc.</td>
</tr>
<tr>
<td>• NANO-X GmbH</td>
</tr>
<tr>
<td>• Nano Hygiene Coatings Ltd</td>
</tr>
<tr>
<td>• Nelum Sciences</td>
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<tr>
<td>• nGimat Co.</td>
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<tr>
<td>• Oak Ridge National Laboratory</td>
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<tr>
<td>• Percenta AG</td>
</tr>
<tr>
<td>• Resodyn Corp.</td>
</tr>
<tr>
<td>• Ross Technology</td>
</tr>
<tr>
<td>• Sandia National Laboratory</td>
</tr>
<tr>
<td>• Seashell Technologies</td>
</tr>
</tbody>
</table>
Self-cleaning (Photocatalytic)

Table 10: Market summary for self-cleaning (photocatalytic) coatings

<table>
<thead>
<tr>
<th>Main markets</th>
<th>Glass, hygiene, sanitary.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total market 2012</td>
<td>$850 million</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>100%</td>
</tr>
<tr>
<td>CAGR to 2020</td>
<td>7.87%</td>
</tr>
<tr>
<td>Total market 2020</td>
<td>$1.2 billion</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>100%</td>
</tr>
<tr>
<td>Nanocoatings market 2020</td>
<td>$2.2 billion</td>
</tr>
</tbody>
</table>

Self-cleaning coatings based on photocatalysts are currently suitable mainly for exterior use for inorganic surfaces and coatings, but photocatalytic materials operating at the wavelength of visible light are also widely studied. Industries impacted by self-cleaning photocatalytic coatings include:

- Architectural glass and construction (including road)
- Medical (self-disinfecting coatings)
- Food production and packaging
- Water purification
- Air purification (indoor)
- Solar coatings.

Nanoparticles

Photocatalysts boost chemical reactions under irradiation with light. This is particularly true for the decomposition of organic substances such as fats, oils or even microbes. The catalytic efficiency is considerably enhanced by the utilization of nanoscale photocatalysts; with TiO2 the most commonly used photocatalyst.

Nanostructured TiO2 possesses high specific surface area, high pore volume and pore size, high activity, and low density. These properties increase the accessible surface area and mass transfer for organic pollutant adsorption, resulting in better photocatalytic performance, since photocatalytic reactions are based on chemical reactions on surfaces.

Applications make use of the self-cleaning, antifogging, anti-microbial or water cleaving properties. In indoor environments, most surfaces, e.g. ceramic tiles, windows glass or paper, are gradually covered with organic matter such as oils, dirt, and smoke residue and become fouled. Transparent TiO2 coatings can be completely unobtrusive, causing no readily discernable changes in the substrate colour or transparency, but they can decompose organic matter as it deposits.

Markets

Nano-TiO2 (coated with 10-20nm layer of TiO2) self-cleaning coatings greatly benefit building maintenance, especially for skyscrapers, as they reduce the need for costly surface cleaning. Various types of surfaces with TiO2 can be covered to make them self-cleaning under sunlight as well as room light. Thus, surfaces based on paints, ceramics, glass, cementitious materials containing active photocatalytic titania nanoparticles have widespread applications to create environmentally clean areas within their proximity. Numerous applications have been developed from utilizing the photocatalytic reaction of TiO2:

- **Self-Sanitizing Surface**: Photocatalyst coating is utilized as a hygienic coating to reduce bacteria and virus contamination. This coating removes the organic matter necessary for bacteria growth. The strong oxidation mechanism also eliminates any bacteria by causing lesion of cell membrane and lysing of cell content.
- **Self-Cleaning Coating**: Building’s exterior surface benefit from these sustainable photocatalytic coatings by eliminating any contaminants that are causing the building to become dirty such as the oil content from car exhausts and any mold or mildew stains.
- **Reduce Indoor Air Pollution and Sick Building Syndrome**: Photocatalyst coating and products control Sick Building Syndrome by removing Volatile Organic Compounds emitted from building material and furniture and create a purer space for comfortable living and working conditions.
- **Reduction of Air Pollution**: Photocatalytic oxidation reduces hydrocarbon waste produced from industrial factories burning fossil fuel or coal.
- **Waste Water Treatment**: Photocatalysts can replace chlorine to be more effective and a much safer alternative oxidation methods to water purification. Photocatalytic oxidation can remove bacteria, organic toxins,
dioxins, and other chemicals in water systems without introducing other chemicals. Nano-TiO2 coatings are widely commercially available and have been used in (mainly in the Japanese and European markets) in water and air purification, self-cleaning glass, concrete products and a variety of coatings applications. Photocatalytic coatings have been applied to numerous buildings in Japan including Chuba International Airport Terminal. Photocatalyst coatings have been proven to combat Bird Flu and SARS infections in high risk areas. Hundreds of hospitals and thousands of buildings in Asia and recently in Europe were coated to protect property against deadly infections and environmental pollution damage. The market for photocatalytic technology in Japan has experienced significant growth in the last decade and was worth over $1 billion million in sales in 2012 (Photocatalysis Industry Association of Japan). The general sales volume for clean-up technologies has increased greatly in recent years, such as photocatalytic air-purifiers, especially in Asia. Asia and Europe are the largest markets, with little traction at present in the United States.

Table 11: Self-cleaning (Photocatalytic) nanocoatings—Principles, Properties, Applications and Companies

<table>
<thead>
<tr>
<th>Principle</th>
<th>Properties</th>
<th>Effect</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Nanoscaled anatas type titania particles in an inert binder</td>
<td>• Good adhesion on metals and glasses</td>
<td>• Anatas type photocatalytic titania nanoparticles in an photocatalytically non-degradable matrix</td>
<td>• Removes odor, greasy components</td>
<td>• Not easy to repair</td>
</tr>
<tr>
<td>• Stable interface substrate/coating</td>
<td>• High chemical resistance against solvents and acids</td>
<td>• Excitation by environmental UV-rays</td>
<td>• Kills bacteria, viruses (claim conflicts with biocides legislation)</td>
<td>• Non durable</td>
</tr>
<tr>
<td>• Wet coating technologies/chemical nanotechnologies</td>
<td>• Highly transparent by nanodimensioned inorganic components</td>
<td>• Superhydrophilic surface (antifogging)</td>
<td>• Invisible</td>
<td>• Chemical attack by bird dropping et cetera</td>
</tr>
<tr>
<td></td>
<td>• Glass-like surface hardness</td>
<td>• Self-cleaning effect by degradation of organic and noxious materials</td>
<td>• Several types commercially available</td>
<td>• Easily mechanically damaged</td>
</tr>
<tr>
<td></td>
<td>• Application technology commercially available, e.g. spray, dip, flow or roller coating</td>
<td></td>
<td>• Organic dirt can be destroyed by ultraviolet light and will be swept away by water</td>
<td>• Not all types applicable on existing surfaces</td>
</tr>
</tbody>
</table>

The market for photocatalytic technology in Japan has experienced significant growth in the last decade and was worth over $1 billion million in sales in 2012 (Photocatalysis Industry Association of Japan). The general sales volume for clean-up technologies has increased greatly in recent years, such as photocatalytic air-purifiers, especially in Asia. Asia and Europe are the largest markets, with little traction at present in the United States.
Table 9: Self-cleaning (Photocatalytic) nanocoatings - Principles, Properties, Applications and Companies

<table>
<thead>
<tr>
<th>Applications</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High humidity areas (e.g. bath rooms)</td>
<td>• Bioshield Inc.</td>
</tr>
<tr>
<td>• Architectural units</td>
<td>• Caparol</td>
</tr>
<tr>
<td>• Automotive parts</td>
<td>• Carrier Corp</td>
</tr>
<tr>
<td>• Machines/covers</td>
<td>• Cristal</td>
</tr>
<tr>
<td>• Clinical surfaces</td>
<td>• Daikin Ltd.</td>
</tr>
<tr>
<td>• Pharmaceutical packing</td>
<td>• FN Nano, Inc.</td>
</tr>
<tr>
<td></td>
<td>• Green Earth Nanoscience, Inc.</td>
</tr>
<tr>
<td></td>
<td>• Green Millennium Inc.</td>
</tr>
<tr>
<td></td>
<td>• Hiranuma Industries</td>
</tr>
<tr>
<td></td>
<td>• Hitachi Home and Life Solution</td>
</tr>
<tr>
<td></td>
<td>• Integrated Surface Technologies, Inc.</td>
</tr>
<tr>
<td></td>
<td>• Italcementi Group</td>
</tr>
<tr>
<td></td>
<td>• JFE Building Materials</td>
</tr>
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<td></td>
<td>• KRONOS</td>
</tr>
<tr>
<td></td>
<td>• Mitsubishi Plastics</td>
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<tr>
<td></td>
<td>• Nanopower Co.</td>
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<td></td>
<td>• Nippon Soda</td>
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<tr>
<td></td>
<td>• n-tec GmbH</td>
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<td></td>
<td>• Panahome</td>
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<td>• Pilkington</td>
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<td>• PPG</td>
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<td></td>
<td>• Saint-Gobain</td>
</tr>
<tr>
<td></td>
<td>• Sekisuo Plastics</td>
</tr>
<tr>
<td></td>
<td>• Sto Group</td>
</tr>
<tr>
<td></td>
<td>• Sumitomo Metal Industries</td>
</tr>
<tr>
<td></td>
<td>• Taiyo Kogoyo</td>
</tr>
<tr>
<td></td>
<td>• Toshiba Lightec</td>
</tr>
<tr>
<td></td>
<td>• Toto Ltd.</td>
</tr>
<tr>
<td></td>
<td>• UBE Industries</td>
</tr>
</tbody>
</table>
UV-resistant nanocoatings

Table 12: Market summary for UV-resistant nanocoatings

<table>
<thead>
<tr>
<th>Main markets</th>
<th>Wood, exteriors, textiles, paints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total market 2012</td>
<td>$365 million</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>3.5%</td>
</tr>
<tr>
<td>CAGR to 2020</td>
<td>4.9%</td>
</tr>
<tr>
<td>Total market 2020</td>
<td>$535 million</td>
</tr>
<tr>
<td>Nanocoatings %</td>
<td>9%</td>
</tr>
<tr>
<td>Nanocoatings market 2020</td>
<td>$48 million</td>
</tr>
</tbody>
</table>

Nanoparticles can provide improved UV resistance for solvent, waterborne and UV coatings. Transparent UV-absorbing or UV-blocking coatings currently have two main applications: as a UV-protecting lacquer for wooden surfaces, and as a UV-barrier coating deposited on the surface of polymer-based products or devices to slow down their deterioration. As the intensity of ultraviolet (UV) radiation increases every year, effective methods to block UV rays to protect human skin, plastics, timber and other polymer materials are urgently sought. UV radiation can also cause severe damage in textiles, plastics, paints and timber products in the forms of discoloration, chalking and reduced mechanical properties. Therefore, the development of effective UV-shielding materials is of great importance to our health, society and environment.

Nanomaterials
Nanoparticles that contain functional coatings to achieve UV-blocking properties have been developed during the last decade. Zinc oxide (ZnO), titanium dioxide (TiO₂) and cerium oxide (CeO₂), nanoparticles are used for UV light protection products for lacquers. Nanoparticles display a significant increase in effectiveness of blocking UV light compared to natural material due to their large surface area to volume ratio.

Markets
In textiles, the UV-blocking property of a fabric is enhanced when a dye, pigment, delustrant, or ultraviolet absorber finish is present that absorbs ultraviolet radiation and blocks its transmission through a fabric to the skin. Textiles serve as important materials for UV protection in many applications. Nano-TiO₂ and ZnO is being applied for UV protection in textiles. Products on the market include Belfasun from Pulcra Chemicals, which contains nanoparticulate zinc oxide and UV cotton textiles with nanosilver coatings from Geckoline Sportswear GmbH. ZnO nanoparticles have also been incorporated into the surface of cotton and wool fabrics. The addition of ZnO increases the mechanical strength of both fabrics and results in an UV absorbing fabric. The UV absorption spectrum of ZnO is broader than TiO₂. ZnO has additional functionality, including antifungal and antistatic properties that TiO₂ cannot offer. Nanoparticles have also been utilized as additives in coatings intended to reduce the discoloration of clear-coated wood exposed outdoors. Altana (www.byk.co.jp/products/pdf/shownews_nanotech13_en.pdf) produces NANOBÝK® UV absorbers based on cerium oxide or zinc oxide that remain stable and provide long-lasting protection.
**Table 13: UV-resistant nanocoatings - Principles, Properties, Applications and Companies**

| Principle | • Decrease in light scattering as a particle diameter approaches nanosize. Photochemical degradation caused by UV rays is a common mode of failure of most of coating systems. It causes the oxidation and decomposition of polymer films along with inorganic or organic pigments. Organic UV stabilizers also undergo deterioration after certain periods. Using nanoparticles like titania or zinc oxide improve UV resistance property by not only absorbing but also reflecting those harmful rays. Also, they are not easily destroyed by UV rays and hence can increase the life span and weather resistance of paints.
• UV-protective, nanocomposite coatings are made by embedding nanocrystalline TiO2, ZnO, SiO2 and Al2O3 particles in a polymer matrix. The benefits accrued by incorporating nanoparticles into a polymer matrix become economically driven when several advantageous properties are obtained simultaneously, compared with conventional materials, i.e. transparency with UV-protection |
| Properties | • ZnO and TiO2 nanoparticle-embedded coatings effectively protect the surfaces from UV radiation, even at lower loading levels, than do micron size particles
• Non-toxic and chemically stable under exposure to both high temperatures and UV
• Nano-sized titanium dioxide and zinc oxide more efficient at absorbing and scattering nano UV radiation than conventional size, and are thus better able to block UV. This is due to the fact that nanoparticles have a larger surface area per unit mass and volume than the conventional materials, leading to an increase in the effectiveness of blocking UV radiation. |
| Effect | • TiO2, ZnO, SiO2 and Al2O3 particles provide extended protection in semi-transparent stains and provides long-term protection from harmful UV radiation in harsh environments
• UV absorbers provide long-term gloss retention and color fastness keeping damaging UV radiation away from the polymer or paint layer that they are protecting and will not impart color change |
| Applications | • Electronics, textiles, varnishes, cosmetics and the paint industry.
• Exterior protection. In addition to appearance, the particles help improve adhesion, tannin blocking and provide improved coating durability
• Polymer materials such as Kevlar that are susceptible to UV degradation may be protected by appropriate coatings
• UV-blocking treatment for cotton fabrics. Includes UV protective swimsuits and sunsuits, sun protective rash shirts (rash vests), swim shirts and swim shorts, UV protection surf shirts and board shorts, sun hats and UV protective wear for babies, including romper style UV suits, sunsuits and legionnaire caps. |
| Companies | • Altana
• Behr Paints
• Bühler AG
• Nanophase
• Nanoverere Technologies, Inc.
• XL-Lutz |
The icing of surfaces is a major problem which impairs the function of those surfaces and incurs significant costs. For example, the ice storm of 2008 caused serious damage to power systems in Southern China, with more than 100 billion yuan ($16 billion) in direct economic losses. Ice and wet-snow adhesion and excessive accumulation on exposed structures and equipment is well known as a source of numerous types of failures and malfunctions in cold-climate regions. Industries affected include machine building, aviation, power transmission, maritime, trains, automotive, refrigeration, construction and wind turbines. The effects of icing include increased weight, impaired function of equipment, longer maintenance time and downtimes and human safety issues. According to the Environmental Protection Agency, 25 million gallons of deicing agents are applied to aircraft at U.S. commercial airports each year. The aviation industry is also using energy-intensive pneumatic and electric anti-icing systems on aircraft to prevent ice formation on wings and other surfaces. Also in numerous other machine construction and structural technology applications, surface freezing can cause malfunctions, such as in antennas and wind turbine wings. Nanocoatings are under development for several applications.

Nanomaterials

Ice-phobic surfaces that have been developed generally utilize lotus leaf-inspired superhydrophobic surfaces to reduce ice or snow accumulation. However, these surfaces fail in high humidity conditions due to water condensation and frost formation and even lead to increased ice adhesion due to a large surface area. Under a frost-free environment (e.g., low humidity conditions), superhydrophobic surfaces show promising behavior in preventing ice formation, at temperatures as low as -25 to -30°C. However, recent studies have shown that these surfaces, may induce ice nucleation at an even faster rate than smooth surfaces of the equivalent materials at high humidity conditions.

Markets

GE Global Research is developing anti-icing nanocoatings. In addition to dramatically reducing ice adhesion, these surfaces now have been shown to significantly delay the onset of ice formation in simulated atmospheric icing conditions. The company are targeting applications in the aviation and wind power industry. Oil and gas companies are also seeking to exploit icephobic coatings for exploration in cold regions. Statoil ASA and the Nanomechanics Lab at the Norwegian University of Science and Technology are developing anti-icing coatings for potential application in the Arctic region where 20% of the world’s resources. Due to the low temperature, exploration can be compromised due to the exposed structures and equipment being affected by ice accretion and adhesion, resulting in damage, degraded reliability and occasional loss of lifetime. IceWind is a 4 million euro project funded by the Norwegian Research Council that is investigating the use of carbon nanotubes in a coating or film absorb MW radiation and generate heat for anti-icing of wind turbine blades. More than 5% of annual production loss due to icing in cold climates.
<table>
<thead>
<tr>
<th><strong>Table 15: Anti-icing nanocoatings-Principles, Properties, Applications and Companies</strong></th>
</tr>
</thead>
</table>
| **Principle** | • Minimization of free surface energy by chemical nanotechnology  
• Self organizing anti-adhesion groups on nanostructured surface |
| **Properties** | • Simple application e.g. by spraying and subsequent thermal treatment  
• Translucent  
• Good adhesion on the substrate without difficult pretreatment  
• Low free surfaces energy  
• Static water contact angle (CA)>150°, superhydrophobic |
| **Effect** | • Block ice formation  
• As with anti-fogging application, the coating keeps water or ice from being able to stick to the nanostructured surface, and it rolls off |
| **Advantages** | • Reduced ice adhesion  
• Invisible  
• Scalable to large surfaces |
| **Disadvantages** | • Durability  
• Easily mechanically damaged  
• Not always easy to repair  
• Not all types applicable on existing surfaces  
• Fail in high humidity conditions due to water condensation and frost formation  
• Can lead to increased ice adhesion due to large surface area |
| **Applications** | • Transportation (aircrafts, cars and trains)  
• Cooling units  
• Wind energy plants  
• Bridges  
• Antennas and transmission lines  
• Rotor blades |
| **Companies** | • Battelle  
• Cg2nanocoatings  
• GE Global Research  
• NanoSonic  
• Nanovere  
• NeverWet  
• Statoil ASA |
Nanomaterials in Construction

Carbon nanotubes
Tesla NanoCoatings Ltd. (www.teslanano.com) produces a range of corrosion-resistant steel coatings, Teslan, incorporating CNTs. The product is a two-coat system consisting of a primer and topcoat developed in collaboration with the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL).

Graphene
The annual costs related to corrosion have been estimated to be nearly $276 billion and represents 3.1% of the U.S. Gross Domestic Product. It has been demonstrated that graphene coatings retards microbially-induced galvanic corrosion (MIC) of metals for extended periods of time (2700 hours) as they prevent access of microbes to the surface, form a protective barrier and protect the surface from microbial byproducts that enhance Ni dissolution. A recent study however indicated that although graphene (http://pubs.acs.org/doi/abs/10.1021/nn4014356) offers effective short-term oxidation protection, over long time scales it promotes more extensive wet corrosion than that seen for an initially bare, unprotected surface.

Silicon dioxide
Silicon dioxide/silica nanoparticles (Nano-SiO2) are applied across a raft of industries, in coatings, in solar cell applications, high temperature insulators, gas sensors, plastics, polymers and wires. In coatings applications they provide improved scratch and abrasion resistance, corrosion-resistance and superhydrophobic and easy-clean properties.
Depositing hydrophilic silicon dioxide nanolayers on various substrates (e.g. steel, aluminum, plastics, glass) give the surface functional characteristics such as easy-clean, anti-dirt, anti-fog and anti-drip. The coating are completely transparent and has no impact on the visual appearance of the substrate. There is no change in color or gloss of e.g. pre-painted metal (steel and Al). The nanocoatings is also durable during outdoor exposure. BASF (www.basf.com) produces inorganic silicon oxide nanoparticles in the COL.9® binders that are incorporated into organic polymer particles of water-based dispersions. After application and drying, the inorganic nanoparticles form a homogeneous three-dimensional dirt repellent network which results in a very hard and hydrophilic surface that provides an excellent moisture barrier but remains permeable to water vapor. Applications are in facade coatings. Buhler Partec (www.buhlergroup.com) uses a Nano-batch dispersion approach for the surface modification of SiO2 nanoparticles with acrylic-groups and their introduction into acrylic-based formulations to give radiation curable nanoparticle composites. The nano surface-sealing products manufactured by Partec, “Nanorepel”, are dirt-repellent and easy-to-clean coatings that seal untreated, absorbent and non- absorbent surfaces. They produce the dispersions in bead mills. They add solvent and special surfactants to suspend the nanoparticles and to deter their re-agglomeration. Other companies producing nanostructured coatings incorporating silicon dioxide in this application area include Nano-Care (www.nanocare-ag.com) and Nanosol AG (www.nanosol.com).
Silica nanoparticles provide improved scratch and abrasion resistance in coatings. Micro hardness, storage modulus and temperature resistance are increased by these coatings and they also offer transparency. Cetelon Nanotechnik GmbH (www.cetelon.de) develops and sells a series of acrylate nanocomposite coatings that contain up to 30% of nano-sized silica. The use of special surface grafted silica nanoparticles ensures the transparency and low viscosity of the coatings.

Titanium dioxide
Titanium Dioxide is used in applications that require high opacity or whiteness, corrosion resistance or photocatalytic activity. Bulk Titanium Dioxide and Nano Titanium Dioxide are two totally different materials. Titanium Dioxide is mainly used as white pigment for paint and cosmetic industry and most in micron particle size. Nanoscale titanium dioxide (nano-TiO2) has a much greater surface area of a given mass or volume of nanoparticles compared to an equivalent mass or volume of conventional TiO2 particles, affording greater potential for properties such as catalytic activity and UV
absorption at certain wavelengths. Photocatalytic nano-TiO2 has been developed and extensively applied due to its nontoxicity, high catalytic activity, strong self-cleaning characteristics, and low cost. The photocatalytic process of TiO2 involves the generation of electron-hole pairs during exposure to light. These holes are able to react with nearby molecules to produce oxidants. The reaction of these particles with water produces the hydroxyl radical (OH-). In the case of oxygen, the result is the superoxide molecule.

Nano-TiO2 is utilized in self-cleaning surface coatings and UV-resistant coatings and paints. Commercially available brands of nano-TiO2 vary in particle size, surface area, purity (e.g., due to doping, coating, or quality control), surface characteristics, crystalline form, chemical reactivity, and other properties. Nano-TiO2 is available in pure anatase, pure rutile, and mixtures of anatase and rutile. In general, anatase nano-TiO2 is more photocatalytic than the rutile form, and nanoscale rutile is less photoreactive than either anatase and rutile mixtures or anatase alone.

Nanostructured coatings are particularly suited to protecting the surface of various construction materials such as glass, concrete, sand limestone or marble from environmental influences like water staining, moss, algae as well as soot and oil stains. Nano-TiO2 is used for self-cleaning, air-cleaning and antibacterial effects in construction materials (Paints and coatings on glass). When exposed to solar radiation Nano-TiO2 acts as a catalyst for photodecomposition of pollutant molecules adsorbed on its surface and transformation into nontoxic compounds. TiO2 coatings can be completely unobtrusive, causing no readily discernable changes in the substrate colour or transparency, but they can decompose organic matter as it deposits. Thus, various types of surfaces with TiO2 can be covered to make them self-cleaning under sunlight as well as room light. Surfaces based on paints, ceramics, glass, cementitious materials containing active photocatalytic titania nanoparticles have widespread applications to create environmentally clean areas within their proximity.

De Cie GmbH (www.decie.de) produces nano-TiO2 glass, leather, metal, stone and wood coatings. Their Anti-Fog coating incorporates nanoscale titanium dioxide and hybrid polymer. The sol-gel process is used for producing the coating and the average thickness of the coating is 30-100nm, depending on application.

UV-Titan from Merck Performance Materials (www.merck-performance-materials.com) is a range of ultra-fine, surface treated, and transparent titanium dioxide with uses in automotive coatings, wood lacquers, and plastics. It is used to provide UV protection in transparent lacquers and plastic (UPVC window profiles) applications. As an inorganic UV screen, it gives long lasting protection against the darkening of wood substrates and helps to maintain the wood’s natural look. UV-Titan can also be used in metallic effect automotive coatings, where it influences the flip/flop effect of the metallic
pigment. Photocatalytic TiO2 coatings have been demonstrated to be more long-lasting and effective than standard antibacterial cleansers. The antibacterial efficiency of TiO2 is not determined by surface area but by the ability to generate active carriers resulting eventually in the formation of effective chemical species such as peroxides (hydrogen peroxide). Photocatalyst nanocoatings have proven to combat Bird Flu and SARS infections in high risk areas. Hospitals and buildings in Asia and recently in Europe have been coated with nano-TiO2 coatings to protect property against deadly infections and environmental pollution damage. Gens-Nano-TiO2 coating from MCH Nanosolutions (www.mchnanosolutions.com) transforms a treated surface into an antibacterial, anti-fungal, mold free surface, while purifying the air. Self-cleaning and other functions will work in the presence of light to protect a building’s interior and exterior from environmental contamination. nanoCotz™ Eco-Refresh from Inspiraz (www.inspiraz.com.sg) is a nano-TiO2 and Titanium Phosphate catalytic coating that decomposes organic sources or odor and bacteria for walls & ceilings of building/home interior, upholsteries, curtains/blinds, air conditioning filters etc.


Aluminium oxide
Alumina nanoparticles are added to the coating of headlight parts, windscreens, optical lenses, coatings for wood floors, safety glasses, electronic displays, and polycarbonate panels to make them scratch- and wear-resistant. BYK-Chemie, among other producers, currently markets alumina nanoparticles for these applications. Alcoa produces nanoscale alumina for applications mainly in the energy industry. Applications include offshore oil and gas drilling systems, high-efficiency power transmission, next-generation lighting, energy-efficient buildings and transportation systems, and green packaging. In oil and glass drilling, applications are mainly for corrosion, scratch, wear resistant and thermal barrier coatings. Nanophase Technologies (www.nanophase.com) produces NanoArc® Aluminum Oxide for surface coatings and films that provides long-term scratch resistance without significantly impacting optical clarity, gloss, color, or physical properties. Nanocomposite alumina coatings can be used in the automotive industry as clear top paint coats. Alcoa and OJSC RUSNANO are producing oil and gas aluminum drill pipe coating with wear resistant nano-alumina coatings for harsh corrosive drilling environments. The anti-wear nanocoating is expected to extend the life of the aluminum pipe by approximately 30% to 40% in aggressive and corrosive drilling environments compared to uncoated aluminum pipes.

Zinc oxide
ZnO-particles act as inorganic UV-filters by reflecting the incident light. Transparent ZnO-nanoparticles are increasingly utilized with the larger surface making their protection functionality much more effective. The same holds for UV-protection of e. g. lacquer films and polymer surfaces. Nanocomposite coatings incorporating ZnO nanoparticles show higher protection against UV radiation (accelerated weathering and outdoor exposure) compared with acrylic latex paint. NanoArc® Zinc Oxide from Nanophase is used for protecting facades and wood from outdoor weathering caused by UV radiation.

Nanocellulose
Nanocellulose is being developed to improve the mechanical properties (abrasion and scratch resistance) of water-based polyurethane varnishes and paints. Intensive dispersion of disintegrated cellulose fibrils in water produces a stable gel – even for solid contents as low as approx. 2%. Cellulose fibril networks consequently exhibit a high water storage capacity. This property makes the transparent fibrils ideal for use in paints, for example, where the dispersion behaviour and strength characteristics can be substantially enhanced.
Nanocoatings are opening up new market opportunities in the global coatings arena. Despite the market being affected by the global economic recession, product innovation and the need to meet stringent environmental regulations is driving demand across a wider range of markets.

01 i ion-mask™: The ion-mask™ treatment of footwear and textile products delivers reduced water uptake with no loss of breathability. The company’s splash-proof liquid repellent nanocoatings have been applied to Motorola and TCL Communication smartphones and tablets. They are a leading materials provider in this growing market.

02 Clarity Defender® PLUS: A self-assembling thin film that coats automotive glass and mirrors with an invisible, water-repellant nano-barrier. Independent tests prove these repellents can increase visibility 34% on a rainy night, which can add a full second to response time.

03 TripleO coating: The tripleO coating is made of nano-scale acrylic polymer beads. The company’s coatings have been utilized by Easyjet and British Airways on their aircraft exteriors.

04 X-Clean: The X-Clean Brand allows for prevention of surface defects for easy-to-clean surfaces with nano-effect in the areas of protection against soiling for glass, ceramics and metal, protection against graffiti and demoulding aids.

05 Herbol-Symbiotec: A facade coating which incorporates the advantages of both organic and inorganic coatings in a single product, exhibits much higher dirt pick-up resistance and colour retention than traditional materials due to the nanotech-based formulation.

06 Oxylink™: Buhler Partec produces Oxylink™ an additive for waterborne coatings. The use of Oxylink™ leads to a sustainable improvement of waterborne coating systems. Nanorepel™ is a dirt repellent coating that can be applied glass, ceramics, metal, wood, textile, leather, concrete, stone and other mineral substrates. Buhler is an established player in these markets and has been for a number of years.


08 FEPORID® 388: DFE Chemie GmbH produces a nanotechnology based pickling inhibitor used as an additive to acid to protect steel surfaces against acid attack. This prevents the all too typical over-pickling and thus results in a higher surface quality of the steel.

09 LIFEKER®: Nanophos SA The company co-develop with Keraben LIFEKER®, a line of self-cleaning and self-sterilizing ceramic tiles.

10 WaterBlock: A super-hydrophobic nanocoating that has been applied to a line of back-lit magnetic compasses by NavELite, and the TAG Heuer RACER Sub-Nano—a limited edition, Android-based smartphone.
## Nanocoatings market supply

### Table 16: Nanocoatings market supply chain

<table>
<thead>
<tr>
<th>Tier</th>
<th>Supply Chain and Companies</th>
</tr>
</thead>
</table>
  • Sales directly to application developers  
  • Sales directly to OEMs |
| 1    | Tools and equipment providers  
  • Sales to manufacturers and application developers |
| 2    | Research Labs  
  • Development of production methods  
  • Collaboration with materials companies and product developers |
| 4    | Intermediate developers (e.g. PPG, Dupont, Diamon Fusion, Nanogate, Nanokote, GXC Coatings, Nippon Soda, n-tec GmbH)  
  Application developers/Large Materials Companies  
  • Purchase nanomaterials from producers and incorporate into products  
  • Produce materials in-house or in collaboration with materials producers/research centres  
  • Collaboration with OEMs to develop final product  
  • Direct sales to markets |
  • Develop products in house-materials purchased from graphene producers  
  • Develop products in collaboration with intermediate developers  
  • Direct sales to end user markets |
Nanomaterials are particularly suited to protecting the surface of various construction materials such as glass, concrete, sand limestone or marble from environmental influences like water staining, moss, algae as well as soot and oil stains; and can also function as corrosion inhibitors for reinforced steel. Nano additive paints and surface coatings are commercially available that create a low energy facing thus rendering a building surface highly hydro- and oleophobic, thereby helping to prolong maintenance cycles and reduce cleaning.

**MARKET POTENTIAL**

**Photocatalytic**

Nano-TiO₂ photocatalytic coatings are the most wide-spread application ascribed to nanotechnology in the construction industry. There are already a great number of buildings worldwide which have been treated with it. Such coatings greatly benefit building maintenance, especially for skyscrapers, as they reduce the need for costly surface cleaning. Photocatalyst coatings are also used to improve indoor air quality by reducing the amount of volatile organic compound and other toxic chemicals people are exposed to.

**MARKET POTENTIAL**

**Thermal**

Commercial window films can gain competitive advantage by embedding nanoparticles into plastic films later applied to glass surfaces. Nano films offer heat absorption and reflective properties while maintaining fairly high levels of transparency. Nanocoatings can be used to reduce heat conduction as well as provide resistance to moisture, corrosion, mold growth and ultraviolet (UV) rays.

**MARKET POTENTIAL**

**Anti-graffiti**

Concrete structures also make profit from nano-enhanced coatings that prevent graffiti and other unwanted stains to adhere on to it. Anti-stick properties of nanocoatings leads to less staining and easy-cleaning-effect on exterior and interior surfaces. Anti-graffiti properties mean that stubborn stains such as graffiti, which in the past called for intensive cleaning efforts can be washed away simply with a high pressure hose.

**MARKET POTENTIAL**
The integration of engineered nanoparticles in façade coatings may lead to improved or new functionalities during their life cycle. Nanomaterials may improve environmental sustainability by saving materials, substituting hazardous substances and improving the durability of the coating. However, extended applications of nanomaterials raise concerns about potential risks for human health and the environment.

Properties

Nanostructured materials are allowing companies to develop the next generation of protective coatings for buildings. Nanoparticles found in construction are carbon-fluoride (CF-) polymers, titanium dioxide (TiO2), zinc oxide (ZnO), silica (or silica fume; SiO2), silver (Ag), and aluminum oxide (Al2O3).

Costs are prohibiting widespread adoption but TiO2 nanoparticles have been widely applied in self-cleaning coatings and carbon nanotubes are being used in concrete to improve strength. Modification or impregnation of resins with nanomaterials could improve hardness, wear and decay resistance in wood products. Dirt repellent protective paints and photocatalytic coatings are the most prominent applications in the construction and exterior protection industry. Dirt collection (accumulation) in building exteriors poses considerable problems for building maintenance. Cleaning such building surfaces is generally done by using detergents accompanied with scrubbing, wiping and high-pressure water jets. These processes have several shortcomings such as use of chemical detergents, high consumption of energy and labour cost. These naturally lead to high maintenance cost; therefore, an effective self-cleaning coating is desirable.

In recent years, self-cleaning coatings using photocatalytic Titanium Dioxide (TiO2) has gained considerable industry attention. With assistance of little UV light from fluorescence source or sunlight, TiO2 offers two unique properties: (a) strong oxidation power, and (b) super-hydrophilicity. Strong oxidation power can be used to kill bacteria attached on the wall, or oxide/remove foul smell from stains in toilets (e.g., TiO2-coated tile and TiO2-coated glass are commercially available). Super-hydrophilic properties allow dirt and stains to be easily washed away with water or by rainfall when such coating is applied to exterior surfaces.

Nanoscale titanium dioxide (TiO2) absorbs UV light and is used as a protective layer against UV degradation. Some forms of TiO2 are photo-catalytic and catalyze the degradation of organic pollutants like algae, PAHs, formaldehyde and NOx under the influence of UV light. Applications are found for practically every surface type that has to be UV-protected, made self cleaning or should assist in the reduction of air pollution. Zinc oxide (ZnO) shows similar photo-active characteristics to TiO2 and can be used for similar applications. Silver (Ag) acts as a bactericide and can be added to all sorts of materials. In construction it is mostly found in coatings.
Aluminum oxide (Al2O3) is used in coatings to interact with the binder material and to add high scratch resistance to this coating. Carbon-fluoride polymers (CF-polymers) are Teflon like nanoparticles that are applied onto a surface to make this surface water and oil repellent. Applications are typically found on glass.

**Glass**

Nanostructured coatings are particularly suited to protecting the surface of construction materials such as glass from environmental influences such as water staining, moss, algae as well as soot and oil stains. Nanoparticles exhibit properties of water/dirt repellency, UV protection, antibacterial, anti-corrosion for application on glass. Strong oxidation power can be used to kill bacteria attached on glass and super-hydrophilic properties allow dirt and stains to be easily washed away with water or by rainfall when the coating is applied to exterior surfaces. There are a number of nanocoated glass products available, with Asia and Germany in particular proving to be strong markets. Pilkington Activ Glass (www.pilkingtonselfcleaningglass.co.uk) uses nano-scaled titania (TiO2) that shows photo-activation with UV light in order to prevent or reduce the soiling of surfaces. Presently, titanium dioxide can only be activated by the UVA present in sunlight. But work is ongoing activating titanium dioxide with indoor light by modifying TiO2 nanoparticles with other elements such as iron and nitrogen so they can absorb light at longer wavelengths. Lab trials show that glass coated with the nanoparticles can be activated by visible light from a lamp to kill Escherchia coli. Applied Thin Films, Inc. (www.atfilminc.com) produces THMC, a proprietary multilayer coating stack specifically designed for applications where high visible transmission is desirable and infrared thermal radiation is rejected thus producing energy efficient windows. CTC Nanotechnology GmbH (www.ctc-nano.de) produces NANOIDENT® Supraperl Forte, a nanobiogenic ultra-thin high-capacity coating for glass surfaces. Application is mainly for glass surfaces on high rises.

**Wood protection**

There are a number of nano-enabled products for the protection and cooling of parquet flooring systems and furniture (interior) and that focus on water (and to a lesser extent oil) repulsion, scratch resistance and UV protection. These transparent protective coating help to cool deck surface temperatures as well as protect the wood from moisture, UV and weathering, while also being resistant to mold and algae growth. High scratch resistant wood lacquers containing nano-SiO2 are Bindzil CC30 (Baril Coatings), Nanobyk 3650 (BYK Additives and Instruments) and Pall-X Nano (Pallmann). Nanobyk 3600 (BYK Additives and Instruments) is an example of a high scratch resistant coating based on the addition of nano sized Al2O3 particles. Nanovations’ (www.nanovations.com.au) Lignol wood coatings are water-based, VOC-free, clear impregnating wood coatings containing nanoscale UV absorbers. Nanovations 3001, designed for use on masonry and concrete surfaces, provides superior water repellency, reduces efflorescence, and provides significantly improved abrasion resistance. Industrial Nanotech, Inc. (www.industrial-nanotech.com) produces Nansulate Deck, for protection and cooling of wooden decks and railings. This clear protective coating helps to cool deck surface temperatures as well as protects the wood from moisture, UV and weathering, while also being resistant to mold and algae growth.

**Paint**

Rheology, settling, surface energy, corrosion resistance and mechanical properties of paint can be improved via the addition of nanoparticles. Adding nanoparticles gives paint scratchproof, easy cleaning, air purifying, UV resistant, water repellence, flame retardancy and antibacterial features. GNS Science (www.gns.cri.nz) and Resene Paints (www.resene.com) have teamed up to develop a hi-tech roof paint containing nano-particles that will be more effective than existing coating products at reflecting summer heat and keeping buildings cooler in summer. Examples of self-cleaning, photocatalytic coatings are Arctic Snow Professional Interior Paint by Arctic paint LTD (TiO2), Cloucryl by Alfred Clouth Lack-fabrik GmbH&Co KG23 (ZnO) and Amphisilan by Caparol.

**Concrete**

Concrete structures are subject to dynamic environments, such as dynamic loads, ultra violet from direct sun-light, continuous expansion and contraction by heat, rain or water splash, impacts from debris, erosion, etc. Concrete structures are subject to dynamic environments, such as dynamic loads, ultra violet from direct sun-light, continuous expansion and contraction by heat, rain or water splash, impacts from debris, erosion, etc.
Figure 2: Mechanism of photocatalytic NOx oxidation on active concrete road.

Figure 3: Jubilee Church in Rome, the outside coated with nanophotocatalytic TiO2 coatings. Photocatalytic titanium dioxide is energized by UV and accelerates the decomposition of organic particulates and airborne pollutants such as nitrous oxide (NOx).

In this condition, most resin coatings deteriorate in a short period of time in the form of cracking, blistering, disbanding, or chalking. Photocatalytic oxidizers can be installed onto the product after the manufacturing process. PCOs that cannot be installed into products during the manufacturing process may be installed using different techniques, such as spraying and dipping methods. With these processes, the lifespan of the PCO will be temporary, usually lasting between five to ten years.

Nanocoatings have been applied to cement products to reduce corrosion and ingress of harmful chemicals. Nanokote (www.nanokote.com.au) has produced NK-TC 01, a coating material that exhibits very high abrasion resistance, high chemical resistance and easy to clean surface properties. The coating material is applied to concrete and cement based substrates to give an opaque satin-gloss or matt finish. German company Nano-Care AG (www.nanocare-ag.com) is manufacturing easy-clean nano-coatings, based on silicon dioxide (SiO2) for cement products. They are used as an invisible, water- and contamination-resistant, UV-stable coating of porous substrate surfaces, regardless of whether the surface is a natural stone such as sandstone, concrete, terracotta, clay brick or stone panelling. Hi-Proguard (http://mui-int.com/Hi-Proguard-for-Concrete.php) is another nano-based product for concrete protection. Cleancorp Nanocoatings (www.cleancorp.de) produces nanoscale anti-graffiti coatings for stone work.
<table>
<thead>
<tr>
<th>Table 17: Nanocoatings in the exterior construction market</th>
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<tr>
<td><strong>Intermediate developers</strong></td>
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<tr>
<td>• Nanovere Technologies</td>
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<td>• Bayer</td>
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<td>• Reef Iran Chemical Industry Complex</td>
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<td>• Industrial Nanotech, Inc.</td>
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<td>• Nanogate</td>
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<td>• Bioni CS</td>
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<td>• Cleancorp Nanocoatings</td>
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<td>• CTC Nanotechnology GmbH, Clou</td>
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<td>• DAW Caparol</td>
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<td>• De Cie GmbH</td>
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<td>• Duraban LLC</td>
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<td>Green Earth Nanoscience, Inc.</td>
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<td>• Green Millennium, Inc.</td>
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<td>• GXC Coatings</td>
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<td>• Haruna (S) Pte Ltd</td>
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<td>• I-Can Nano, ISTN, Inc.</td>
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<td>• NanoCare AG</td>
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<td>• Nanoproofed</td>
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<td>• Nanovations Pty Ltd</td>
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<td>• NANO-X GmbH</td>
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<td>• nGimat Co.</td>
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<td>• n-tec GmbH</td>
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<td>• XL-Lutz</td>
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<td>• PURETi, Inc.</td>
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<td>• Cristal</td>
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<tr>
<td><strong>Product developers</strong></td>
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<td>• Nippon Paint</td>
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<td>• Alcoa</td>
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<td>• Sveza</td>
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<td>• TATA Steel</td>
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<td>• PPG</td>
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<td>• Duravit</td>
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<td>• Roca</td>
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<td>• Erlus</td>
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<td>• Villeroy and Boch</td>
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<td>• Saint Gobain</td>
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<td>• BASF</td>
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<td>• Clariant</td>
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<td>• Panahome</td>
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<tr>
<td><strong>Target markets size according to industry estimates</strong></td>
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<tr>
<td>• U.S. construction chemical industry is valued at $7.7 billion (Freedonia).</td>
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<tr>
<td>• The global construction materials market grew by 6.2% in 2010 to reach a value of $655,822.9 million (Data Monitor).</td>
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<td>• In 2015, the global construction materials market is forecast to have a value of $889,017.9 million, an increase of 35.6% since 2010.</td>
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<tr>
<td>• The global green construction materials market is expected to exceed $405 billion by 2015 (GIA).</td>
</tr>
</tbody>
</table>
### Table 17: Nanocoatings in the exterior construction market

| Target markets size according to industry estimates | • The global construction materials market had total revenues of $664.4 billion in 2011, representing a compound annual growth rate (CAGR) of 3.6% between 2007 and 2011 (Marketline).  
• Global photocatalysts market 2009: $ 800 million (BCC)  
• Global photocatalytic coatings market 2010: $62 million (AIST)  
• The cost of damage caused by emissions in 2009, just from the industrial facilities reporting into the E-PRTR (European Pollutant Release and Transfer Register), is estimated as being at least EUR 102–169 billion. Fifty percent of the total damage cost occurs as a result of emissions from just 191 (or 2%) of the approximately 10,000 facilities that reported at least some data for releases to air in 2009. Three quarters of the total damage costs are caused by the emissions of 622 facilities, which comprise 6% of the total number.  
• Sales of photo-catalytic products in Japan was 650 million USD in 2008 (Nanoglobe)  
• Global photocatalyst market 2009 was $1 billion. Japanese market $700 million (Sumitomo Chemical). |

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Advanced Materials-JTJ s.r.o.

DESCRIPTION
The company is a producer of nanoscale photocatalytic coatings. It was founded in 2003.

PRODUCTS
• Manufacturing process Photocatalytic coatings FN®
• Manufacturing process for nano TiO2
• 3D Li-LION Batteries

The photocatalytic air cleaning coatings FN® have been already licensed and distributed in the Czech Republic, Slovakia, Poland, New Zealand, Australia, Canada, Vietnam, Spain, Portugal, Denmark, Sweden, Norway, Island and South Africa. While the largest Czech paint manufacturer Colorlak a.s. supplies exclusively the Czech and Slovak markets, Advanced Materials-JTJ manufactures and distributes the photocatalytic products globally.

Photocatalytic Coatings FN® act as air cleaning systems. The composition is organics, silicate and silicone free, that according to the company are demonstrating 10-100 times higher efficiencies for the pollution removal and bacterial killing than the photocatalytic paints and top coats that are currently on the market. These suspensions effectively clean industrial and exhaust exhalations, organic contaminants from plastics, allergens and many other substances that are threat to human health and lower the quality of our environment. According to the WTO, more than 15% of chronic diseases are caused by bad air quality. A high percentage of allergies, contagious infections, bad odors or darkening of facades are a few examples of the impacts of contaminated air. Man is forced to protect himself and one exciting possibility is the use of photocatalytic coatings FN®. The FN® suspensions represent an advanced air cleaning system indoor. In fact, the coating turns a room into a highly efficient, reliable, low maintenance, low energy consumption air cleaner. The coatings can also be used to clean the air outside. There it works as a life extending facade or concrete protection at the same time. FN® suspensions are applied by brush, roller or spray, similar to regular paints.

TARGET MARKETS
• Sick building syndrome
• Decontamination
• Battery

ADDRESS
Advanced Materials-JTJ s.r.o.
Kamenné Žehrovice 23
273 01
Czech Republic
Tel: +420 774 735 163

WEB
www.amjtj.com
Advenira Enterprises Inc.

DESCRIPTION
Advenira Enterprises Inc., is a Sunnyvale, CA based company

PRODUCTS
The company has developed a novel Solution Derived Nanocomposite (SDN™) technology that allows for low-cost/high-throughput multifunctional coatings deposition on practically any type/shape/material substrate. At present there are several standard approaches for depositing functional nanocomposite films: physical vapor deposition, PVD; chemical vapor deposition, CVD; and several methods for applying a limited number of liquids, in particular the sol-gel process. The latter has many advantages, but its use is limited because the solution precursors have short useful lives. SDN technology is a modification of the sol-gel method that has overcome problems maintaining the precursor solution in its initial state.

TARGET MARKETS
SDN technology has many applications. It can be used to apply coating during manufacture of low-emission architectural glass, for solar cells, displays, microelectronic equipment, and packaging and antibacterial materials.

ADDRESS
Advenira Enterprises, Inc.
788 Palomar Ave.
Sunnyvale, CA 94085
USA
Tel: +1 408-732-3950

WEB
www.advenira.com
ALD Nanosolutions

DESCRIPTION
ALD NanoSolutions (ALDN) is a nanomaterials development company using the platform Polymer ALD™ technology to develop novel barrier films.

PRODUCTS
ALD NanoSolutions’ proprietary technology is based on atomic layer deposition coating chemistries and processing methods developed at the University of Colorado by Dr. Steve George and Dr. Al Weimer for depositing ultra-thin films onto particulate and polymer surfaces. These coating processes, called Particle ALD and Polymer ALD, have been validated, are economically scalable, and suitable for commercial operation.

TARGET MARKETS
ALD on particles has been successfully demonstrated by the company on numerous substrates, such as metals, ceramics, and polymers in many different materials markets including microelectronics, defense, battery systems, consumer products, construction, and biomedical.

ADDRESS
ALD NanoSolutions, Inc.
580 Burbank Street, Unit 100
Broomfield, CO 80020
USA
Phone: +1 (303) 318-4145 x103

WEB
www.aldnanosolutions.com
Alexium

DESCRIPTION
Alexium International Group Limited holds proprietary patent applications for a process developed initially by the US Department of Defense, which allows for the surface modification and attachment of nano-particles or multiple chemical functional groups to surfaces or substrates to provide functions such as water proofing, oil proofing, anti-microbial, non-stick and UV protection.

PRODUCTS
Alexium’s fire retardant treatment for 95% Nylon based products is marketed under the Ascalon™ trade-mark. Alexium’s fire retardant treatment for nylon blended materials such as nylon/cotton (Nyco), is marketed under the Nycolon™ trade mark.

TARGET MARKETS
Applications under development include but are not limited to textiles, paints, packaging, glass and building materials.

ADDRESS
Alexium Inc.
8 Distribution Ct
Greer, SC 29650
USA
Phone: +1 864-416-1060

WEB
http://alexiuminternational.com
Ancatt

DESCRIPTION
The company is a start-up producing anti-corrosion nanocoatings.

PRODUCTS
AnCatt has invented a heavy-duty anticorrosion coating system consists of a unique conducting polymer based primer, a top layer, and an optional interlayer. The coating extends the anti-corrosion performance, because the current anti-corrosion coating can only withstand 4,000 hours of tests. Our coating extends over 13,000 hours of tests.

TARGET MARKETS
The coating system could be used in severe conditions to protect structural steel, pipeline, tanks, bridges, offshore platforms, marine hulls, superstructures, decks, airplane, etc. Current zinc based anti-corrosion coatings are not effective and the known zinc reserve will be depleted around 2020. The regulations are phasing out the toxic heavy-metal based anti-corrosion coating technologies rather sooner. Other heavy-metal free anti-corrosion coating technologies are too weak in performances.

ADDRESS
AnCatt
Central East Coast Near Philadelphia
Newark, 19711
UNITED STATES
Phone: +1 (302) 533-6533

WEB
www.ancatt.com
Bionic Technology BV

DESCRIPTION
Bionic Technology produces inorganic ceramic nanoparticles for application in coatings.

PRODUCTS
The company produces:
• Hydrophobic coatings for glass, ceramic, metal and plastic surfaces
• Anti-Fingerprint- and non-stick-Coating products for stainless steel
• Photocatalytic self-cleaning coating for glass and plastic surfaces
• Hydrophobic coatings for textiles and leather
• Hydrophobic coatings for wood, stone and lacquer
• Antibacterial active products
• Biocide hydrophobic coatings

TARGET MARKETS
• Glass
• Ceramics
• Metals
• Plastics
• Wood
• Textiles

ADDRESS
Bionic Technology Holding BV.
Zeefbaan 18 9672 BN Winschoten
Nederland
Phone: +31 (0) 597 - 434911

WEB
www.bionictechnology.nl
BYK-Chemie GmbH

DESCRIPTION
Buhler Nanotechnology develops and manufactures dispersions of nanoscaled metal oxides by combination of chemical and mechanical expertise. Buhler Nanotechnology is part of Buhler Group, a global leader in the field of process engineering. Buhler operates in over 140 countries and has a total payroll of about 7,800 worldwide. In fiscal 2010, the Group generated sales (turnover) of CHF 1.9 billion.

PRODUCTS
BYK offers nanoparticle dispersions of aluminum oxide, silica, zinc oxide, and ceria under the NANOBYK trade name. The particles are dispersed in a variety of solvents, providing easy handling and simple incorporation via post-addition into a wide range of coatings formulations. Because of the size of the nanoparticles, they do not scatter light and can be added to a coating formulation without affecting its optical properties such as gloss and transparency. Incorporation of nanoparticles also provides a mechanism for efficient dissipation of stress throughout the polymer matrix, preventing catastrophic failure.

TARGET MARKETS
Silica- and alumina-based nanoparticles provide improved scratch and abrasion resistance, while ceria- and zinc oxide-based nanoparticle dispersions provide stabilization against UV radiation (UVA by zinc oxides and UVB by ceria).

ADDRESS
BYK-Chemie GmbH
Abelstraße 45
46483 Wesel
Germany
T: +49 2816700

WEB
www.byk.com
Ceko

DESCRIPTION
Ceko is a Korean-based supplier of Paints, Powder & Varnishes and related products.

PRODUCTS
Nano Primer is an additional coating agent for strengthening adhesion between coating materials and base materials of glass, metal and plastics (PC, PMMA, PET etc). The company also produces anti-scratch and anti-fingerprint nanocoatings.

TARGET MARKETS
• Glass
• Ceramics
• Metals
• Plastics

ADDRESS
CEKO Co., Ltd
4F Joong-II Eines Platz III, 442-13 Sangdaewon-dong, Jungwon-gu,
Seongnam-si, Gyeonggi-Do
South Korea
Tel: 82-31-7333355

WEB
www.ceko.co.kr
CeNano GmbH & Co. KG

DESCRIPTION
CeNano GmbH & Co. KG develops, produces and sells ceramic coatings and sealants based on nano-technology contributing to environment protection. CeNanom GmbH & Co. KG, Germany manufactures nanotol, a universal nano sealant that treats surfaces so that they can be cleaned ecologically. The use of nanotol not only reduces cleaning times by more than 50%, but eliminates the need for all environmentally damaging cleaning agents. Other products include Nanofix, a limescale remover.

PRODUCTS
The company has products for nonporous, textiles and porous mineral substrates that can be used for germ repelling applications.

TARGET MARKETS
CeNano sealants are available for wood, textiles, and mineral substrates such as concrete, plaster, screed, or natural stone. The company owns the complete IP on their products.

ADDRESS
CeNano GmbH & Co. KG
Hochfellnstraße 13
84427 St. Wolfgang
Germany
T: +49 8085946124

WEB
www.cenano.de
CG2 NanoCoatings, Inc.

DESCRIPTION
SME providing research and development in advanced coatings and polymer reinforcement.

PRODUCTS
The company has developed a process to utilize nanoscale properties by first functionalizing nanoparticles and then incorporating them into a base material (polymers, metals, ceramics or composites).

TARGET MARKETS
Anti-Corrosion Coatings
The technology consists of homogeneous thin films using alkoxides with chemically attached ceramic nanoparticles. High temperature oxidation and corrosion can be reduced by coating materials with thin layers of oxides that are chemically resistant and have a high melting point. Such films are particularly useful for metal surfaces and they offer many advantages such as high purity, low-temperature processing and control of the composition.

Anti-Stain Coatings
The technology uses ceramic nanoparticles. These nanoparticles are essentially nano-chemical reactors that can be functionalized in various ways to meet specific requirements.

ADDRESS
CG2 NanoCoatings, Inc.
21 Pine Needles Court, Suite 200
Ottawa
Ontario
K2S 1G5
Canada
T: +1 6134357747

WEB
www.cg2nanocoatings.com
Clariant

DESCRIPTION
Clariant is a global leader in the field of specialty chemicals. Headquartered in Muttenz near Basel, Switzerland, it generated sales of around CHF 8.1 billion in 2006. Its operative business is organised into five divisions: Textile, Leather & Paper Chemicals, Pigments & Additives, Functional Chemicals, Life Science Chemicals, and Masterbatches. In Germany, Clariant is represented by several companies, including its largest company worldwide, Clariant Produkte (Deutschland) GmbH.

PRODUCTS
Clariant develops functional nano-coatings based on polysilazanes and organically modified polysilazanes. These enable particular effects to be achieved such as gas barriers on foils, protection against corrosion, anti-fog anti-fingerprint, anti-graffiti, photocatalysis, easy-to-clean or heat-dissipating.

TARGET MARKETS
Easy-Clean Coatings
Innovative coatings based on composite organic-inorganic nano-particles derived from sol-gel technology allow a broad spectrum of surface modifications. The company offers a versatile range of Easy to Clean (ETC) coatings for the protection of glass, ceramic and metal surfaces. All products are based on fluoropolymer modified nano-particles in solution and can be applied to the substrate by spray application or wiping.
Dispersing Agents
A comprehensive range of dispersing agents for nano-particles based on polymer and surfactant chemistries is available.
Organo-polysilazanes
In addition to its four divisions, Clariant operates so-called incubator business such as organopolysilazane technology. The polysilazane-containing coatings are extremely useful as easy to clean, anti-graffiti, anti-corrosion, heat resistance, high hardness and scratch resistance, and reduction of UV-degradation of underlying pigmented coatings.

ADDRESS
Clariant Produkte (Deutschland) GmbH
Industriepark Höchst
D 561 65926
Frankfurt
Germany
T: +49 61 96757 7893

WEB
www.clariant.com
Cleancorp Nanocoatings

DESCRIPTION
Cleancorp Nanocoatings is a small, privately-owned company of 14 people, established in 1998.

PRODUCTS
The company is involved in the production, R&D and sale of nano surface coatings, nanopowders, additives, anti-bacterial nanocoatings, scratch-resistant coatings, easy-to-clean-coatings, corrosion-protection systems, self-cleaning systems, development and tailor-made systems in co-operation with companies, coatings for automotive, medical industry, textile industry, polymer compounding with nano effects.

The surfaces produced are highly resistant against acids and cleaning products. They are resistant to high pressure and temperatures. Materials used include nanopowdered ceramics, composite materials containing nanocrystals, fibers or powders, nanostructured metals, alloys and polymer materials and their subsequent nanoscale surface functionalization. One criteria they cannot meet is the non-chemical feature which removes the germs itself, but they can provide hydrophobic or superhydrophic surfaces which will reduce the adhesion of germs, bacteria etc. due to their very low surface energy, and they can be removed quite easily from a coating mentioned.

TARGET MARKETS
The company has cooperation with specialized partners and customers for implementation of the process technology. Partnerships exist with Nanoscape, PerPro, and in Italy, Turkey, Russia, China and Azerbaijan. Their products are used in hospitals, senior residences, kindergardens, the textile industry etc. Applications range from anti-graffiti for stone and mineral surfaces, corrosion protection for metals, anti-fingerprint coatings for metallic surfaces, scratch resistant, surfaces for plastics and polymeric substrates, hydro- and oleophobic, breathable coatings for stone and mineral surfaces. Main markets are:
- Chemical Industry: Soaps, detergents, cleaning and polishing preparations
- Medical Technology: Immunology
- Materials: Plastics

They also provide some customers with anti-bacterial plastic (masterbatches) for moulding processes.

ADDRESS
Cleancorp Nanocoatings
Ostpreußenstr. 31
82140 Olching
DFürstenfeldbruck
Germany
T: +49 8142 284875

WEB
www.cleancorp.de
Cotec GmbH

DESCRIPTION
For more than ten years Cotec GmbH in Nidderau has been developing and marketing systems, processes, materials, equipment and wear and tear parts for PVD & CVD thin film and sputter applications (PVD and CVD: physical or chemical vapor deposition).

PRODUCTS
The product portfolio comprises coating materials such as oxides, fluorides, metals, mixed or customized substances, elements for thermal and e-beam evaporators, APS (advanced plasma source) and ion-source parts, crucibles, boats, cathodes, calotte-segments and vibrating quartz crystals. They also offer tungsten filaments, aluminium coils, and sputtering targets of different metals, which possess, like all manufactured materials, a specified degree of purity. These materials enable the production of high-tech, optically active coatings with nanometer-scale precision.

TARGET MARKETS
Easy-to-clean coating affords protection against mechanical stress, watermarks, fingerprints, dust, grease and many other things besides. Added value and additional benefit are created by interface modification with 3D-nanotechnology (anchoring group, molecular chain and functional group).

The use of Cotec’s ultra-hydrophobic and oleophobic coating material DURALONUltraTec in combination with HCS machines (hydrophobic coating systems) ensure a long lasting easy-to-clean coating. The effect will persist over the entire service life of the treated product. Cotec also supplies plasma treatment and nanocoating systems configured for various surface modifications, thus making it possible to secure highly adhesive, corrosion-proof or friction reducing coatings.

ADDRESS
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T: +49 6187907480
WEB
www.cotec-gmbh.com
CTC Nanotechnology

DESCRIPTION
CTC Nanotechnology GmbH is a supplier of systems for nano-bionic surface finishing, developing new types of solutions for steel/stainless steel and plastics, such as anti-fingerprint, scratch-resistant, hydrophobic and oleophobic coatings and paints, as well as vapor-permeable surface coatings.

PRODUCTS
CTC Nanotechnology GmbH currently produces more than 76 different nanobionic products for the treatment of diverse surfaces. The range is divided into three quality grades: consumer, commercial and industrial.

TARGET MARKETS
The products are used for refining industrial surfaces such as facades or glass, and in easy-to-clean and self-cleaning treatments for vehicle windscreens, paintwork, wheel rims or kitchen surfaces made of stainless steel, etc.

ADDRESS
CTC Nanotechnology GmbH
Dörrmühle 4
D-66663 Merzig
Germany
T: +49 5452 93595 21

WEB
www.ctc-nanotechnology.com
De Cie GmbH

DESCRIPTION
The company is a privately owned business producing easy-to-clean and anti-fog coatings.

PRODUCTS
Surfaces such as glass, leather, metal, stone and wood are coated. The nanomaterial for the Anti-Fog coating is nanoscale titanium dioxide and hybrid polymer. For easy-to-clean hydrophobic coatings, silane, ethoxy carbosiloxane, organic polymers, tantaloxid and SiO2 are used. Transparent hard coatings for plastic materials are also developed. Sol-gel process is used for producing the coating and the average thickness of the coating is 30-100nm, depending on application.

Company products include:
• Stone and wood protection: Nano-Stein-Protector
• Wood protection: Nano-Teakholz-Protector
• Glass and ceramics: Nano-Glas-Protector
• Textiles and leather: Nano-Textil-Leder-Protector

TARGET MARKETS
Products are sold at sufficient high margins to cover the development-and production expenses. They are priced preferentially by functional benefit and not to the measurement categories like volume, quantity or mass. The company possesses low mass marketing capabilities.

ADDRESS
De Cie GmbH
Homburger Landstr
148 A, D-60435
Frankfurt
Germany
T: +49 699543020

WEB
www.decie.de
Diamon-Fusion International

DESCRIPTION
Diamon-Fusion International, Inc. (DFI Nanotechnology), is a developer and exclusive licensor of patented hydrophobic nanotechnologies.

PRODUCTS
The company’s flagship product Diamon-Fusion® provides multi-functional characteristics that include: water and oil repellency (hydrophobic and oleophobic), impact and scratch resistance, protection against graffiti, dirt and stains, finger print protection, UV stability, additional electrical insulation, protection against calcium and sodium deposits and increased brilliance and lubricity for application in the automotive industry.

TARGET MARKETS
• Interiors
• Construction
• Automotive.

ADDRESS
DFI-DIAMON-FUSION INTERNATIONAL, INC.
9361 Irvine Boulevard
Irvine, California 92618
USA
Tel: + 1 888 344 4334

WEB
www.dfisolutions.com
Engineered nanoProducts Germany AG

DESCRIPTION
The company is a spin-out from the Institute of New Materials in Germany.

PRODUCTS
• Advanced metal coating technologies (Protection for metal surfaces, new styling possibilities and new functions)
• Hygienic technologies for clean and self sterilizing surfaces
• Nanocomposite parts for optics, plastic and coating technologies, including foil coatings, e. g. for light management
• Nanobinder technologies for high-performance high-temperature insulation and the improvement of oil and gas production.

TARGET MARKETS
The company's coatings are applied to the automotive and aircraft industry, in industrial plants, architecture, optics and multimedia, environment, and life sciences.

ADDRESS
Engineered nanoProducts Germany AG
Max-Planck-Str. 2
66482 Zweibrücken
Germany
T: +49 6332481920

WEB
www.e-p-g.de
Evonik Hanse

DESCRIPTION
Evonik is active in over 100 countries around the world. In fiscal 2010 more than 34,000 employees generated sales of around €13.3 billion and an operating profit (EBIDA) of about €2.4 billion.

PRODUCTS
The company produces nano-scale SiO2 particles for incorporating in 2-pack polyurethane coatings. TEGOTOP®

TARGET MARKETS
• Exteriors
• Interiors.

ADDRESS
Evonik Industries AG
Rellinghauser Straße 1-11
45128 Essen
Tel: +49 201 177-01

WEB
http://hanse.evonik.com/
FN Nano Inc

DESCRIPTION
The company is a photocatalytic coatings producer.

PRODUCTS
The company produces nano-scale FN® photocatalytic coatings to combat sick building syndrome.

TARGET MARKETS
• Exteriors

ADDRESS
FN Nano Inc
5303 Louie Lane #22
Reno, NV 89511
USA
Phone: +1 (775) 825 - 7080

WEB
http://fnnanoinc.com
Green Millenium, Inc.

DESCRIPTION
Company was founded in 2003 and is based both in Japan and USA. Green Millennium Inc. is the international sales and marketing office of SAGA-KON Corporation, one of the most prominent research institutions of photocatalyst technology in Japan.

PRODUCTS
The company produces photo catalytic coating for a range of applications. Titanium dioxide is deposited on surfaces such as tile, glass, metal, paint, concrete and plastic. Film thickness of about 1 microns has been deposited. The technology has been applied to food processing.

TARGET MARKETS
Applications include self-sanitizing surface, self-cleaning coating, reduction of air pollution, waste water treatment.

ADDRESS
Green Millennium, Inc.
425 W. Allen Ave.
#111 San Dimas
CA 91773
USA
T: + 1 9093058882

WEB
www.greenmillennium.com
GXC Coatings

DESCRIPTION
GXC Coatings applies functional coatings based on nanotechnology to glass and polymer substrates. Applications of such coatings are in automotive, optics, microtechnology, sensors, safety, instrument covers, windows and glazing.

PRODUCTS
The company applies functional coatings based on nanotechnology to glass and polymer substrates. Applications of such coatings are in automotive, optics, microtechnology, sensors, safety, instrument covers, windows and glazing. The company’s easy-to-clean or self-cleaning coatings protect value add parts made of glass, plastic or metal from dirt or facilitate the cleaning thereof.

- Easy removal of dirt
- Increased value of your product
- Reduction of cleaning costs and work load
- Value-added comfort
- Premium positioning
- Self-cleaning of outside surfaces (modified product)

Areas of use
- Glazing in the industry and at home
- Control windows in machinery, maritime and plant construction
- Glass elements that are intensively used in kitchens and bathrooms
- Headlights and lighting covers used outside
- Windscreens

TARGET MARKETS
- Glazing in the industry and at home
- Control windows in machinery, maritime and plant construction
- Glass elements that are intensively used in kitchens and bathrooms
- Headlights and lighting covers used outside
- Windscreens

ADDRESS
GXC Coatings
Im Schleeke 27-31
38642 Goslar
Germany
T: +49 5321343086

WEB
www.gxc-coatings.de
Hy-Power Nano, Inc.

DESCRIPTION
Hy-Power Nano Inc. is a subsidiary of Hy-Power Coatings Limited, an industrial coatings service provider. Hy-Power Coatings serves a range of blue chip clients including: Loblaw, McDonald’s, First Capital, HydroOne, Vicwest, Petroff Architects and Walmart. Hy-Power Coatings Limited’s President and Founder, Joseph G. Grzyb, created Hy-Power Nano in 2010.

PRODUCTS
The company is developing a Thermal Liquid Glass nanocoating for glass that maintains light clarity and blocks UV and IR rays.

TARGET MARKETS
• Construction and exterior protection

ADDRESS
Hy-Power Coatings
101A Devon Rd
Brampton
ON L6T 5A4
Canada
T: +1 9057908577

WEB
http://hy-powernano.com
Industrial Nanotech, Inc.

DESCRIPTION
Industrial Nanotech, Inc. develops and commercializes Nansulate(R) specialty coatings for thermal insulation, corrosion prevention, resistance to mold growth, fire resistance, chemical resistance and lead encapsulation in an environmentally safe, water-based, coating formulation.

PRODUCTS
The company produces nanocomposite coatings for pipes, tanks, metallic surfaces and other high heat applications. Nansulate is the Company’s patented product line of specialty coatings that provide thermal insulation, corrosion prevention, resistance to mold growth, lead encapsulation, chemical resistance, and fire resistance in an environmentally safe, water-based, coating formulation. The Nansulate Product Line includes both industrial and residential coatings. The entire Nansulate Product Line includes: Nansulate GP, Nansulate PT, Nansulate Chill Pipe, Nansulate High Heat, Nansulate HomeProtect ClearCoat and HomeProtect Interior, and Nansulate LDX.

Nansulate Product Details
• Temperature Extremes: From -40F to 400F (-40C to 204C)
• Application Temperature Range: 40F to 212F (4C to 100C)
• Coverage Rate: One gallon covers approximately 150-175 sq. ft. of surface area with the recommended minimum three coats of the product required for thermal protection. Actual coverage rate may vary depending on surface texture.
• Designed for high performance industrial maintenance applications or OEM applications. Formulated to allow visual inspection of the substrate through the coating.

TARGET MARKETS
The Nansulate(R) Product Line includes industrial, residential, agricultural and solar thermal insulation coatings.

ADDRESS
Industrial Nanotech Inc.
1925 Trade Center Way, Suite 1
Naples, FL 34109
USA
T: +1 800-767-3998

WEB
www.industrial-nanotech.com
INNOVCOAT Nanocoatings and Surface Technologies Inc.

DESCRIPTION
Innovcoat is a joint venture (50%-50%) nanotechnology company of Materis Group (France) and Inovnano (Turkey).

PRODUCTS
The company is a producer of protective nanostructured coatings.

TARGET MARKETS
• Metal
• Wood
• Plastic

ADDRESS
INNOVCOAT Nanocoatings and Surface Technologies Inc.
Gebze Organize Sanayi Bö. Kemal Nehrozoğlu Cad.
Teknopark 1.Üretim Binası 41480 Gebze / Kocaeli
Turkey
Phone: +90 262 678 89 63

WEB
www.innovcoat.com.tr
Inno-X

DESCRIPTION
The Inno-X produces coatings and additives to functionalize surfaces and materials for industrial applications.

PRODUCTS
The company produces water based nanocoatings for wood and mineral surfaces to reduce the use of cleaning agents and extend the lifetime of the product. The coatings are ultra-thin, invisible and have a water vapor passable structure.

TARGET MARKETS
• Exterior protection
• Textiles
• Paint
• Plastic/Polymers
• Agriculture
• Corrosion Protection for Aluminum, Magnesium, Zinc
• Corrosion Protection for Metals
• Heavy Corrosion Protection for Steel

ADDRESS
Inno-X
Tutilostrasse 36b
St.Gallen
Switzerland, 9011

WEB
www.inno-x.ch
Inspiraz Technology Pte Ltd.

DESCRIPTION
The company manufactures antiviral, antimicrobial and hydrophobic coatings based on silver, carbon and photocatalyst nanoparticles.

PRODUCTS
nanoCotz™ Eco-Refresh is a Titanium Dioxide & Titanium Phosphate catalytic coating that decomposes organic sources or odor and bacteria for walls & ceilings of building/home interior, upholsteries, curtains/blinds, air conditioning filters etc.

TARGET MARKETS
The company’s coatings work on almost all surfaces, including plastics, concrete, ceramics, granite, roofing, wood, metal, glass, rubber, etc.

ADDRESS
Inspiraz Technology Pte Ltd
#06-161, Blk 19 Kallang Avenue
339410
Singapore
T: +65 62970880

WEB
www.inspiraz.com.sg
Life Air Iaq Ltd.

DESCRIPTION
The company is Indoor Air Quality, specializing in air purification technology by using “Photo-Catalytic Oxidation” (PCO).

PRODUCTS
PCO technology uses Titanium Dioxide and UV light to decompose and oxidize pollutants such as bacteria, viruses, volatile organic compounds, formaldehyde, nitrous oxides (NOx), and sulfur oxides (SOx).

TARGET MARKETS
The company’s products have already been used in offices, hospitals, cigar rooms, and hotels. The nanocoating technique as well as the physical application of PCO technology is patented and recognized by the Hong Kong Innovative Council. The performance test was done by The Hong Kong Polytechnic University.

ADDRESS
Life Air Iaq Ltd.
Unit 7, 1/F, Fu Hang Industrial Building,
1 Hok Yuen Street East, Hunghom,
Kowloon
Hong Kong
T: +1 8525270106

WEB
www.lifeairiaq.com
Nadico Technologie GmbH

DESCRIPTION
NADICO Technologie GmbH was founded in 2002. NADICO Technologie GmbH is a specialist in research and development of photocatalytic surfaces treatments.

PRODUCTS
The company produces TitanShield® and TitanProtect® photocatalytic nanocoatings.

TARGET MARKETS
• Interiors
• Exteriors

ADDRESS
NADICO Technologie GmbH
Haus-Gravener Str. 155
40764 Langenfeld
Germany

WEB
www.nadico.de
Nanokote

DESCRIPTION
Nanokote, a division of Australian company Micronisers Pty Ltd works in the research and development of commercial applications for nanotechnology.

PRODUCTS
NK-TC 01 is a coating material that exhibits very high abrasion resistance, high chemical resistance and easy to clean surface properties. The coating material is applied to concrete and cement based substrates to give an opaque satin-gloss or matt finish.

TARGET MARKETS
• Glass coating for shower screens and glass pool fencing.
• Anti carbonation concrete coating and anti graffiti coating.
• Stainless steel anti corrosion coating.

ADDRESS
NANOKOTE PTY LTD
Registered Office Micronisers
Address:
6-8 England Street
Dandenong
Victoria
Australia
3175
Telephone: +61 3 9768 3277

WEB
www.nanokote.com.au
Nanomate Technology

DESCRIPTION
Founded in 1997, NanoMate Technology Group develops, nanoscale chemical products, processes, and services for Chemical Vapor Deposition (CVD), Atomic Layer Deposition (ALD), and nano organo-ceramic coatings.

PRODUCTS
NanoMate® Technology's proprietary conversion and coating process is chromate and heavy metal ion free.

TARGET MARKETS
NanoMate's proprietary metal pretreatment solutions have been used for a variety of applications. For pre-painting and pre-bonding applications, it can replace metal surface pretreatment as well as eliminate or decrease primer usage. NanoMate coating solutions can be applied on materials such as metals, stone, ceramic, cement, plastics and glass. For anti-corrosive applications, NanoMate can eliminate or decrease heavy metal ion usage thereby eliminating or at least minimizing waste disposal requirement. For wear resistance, anti-fingerprint, and lubricating applications, the coating process improves on the performance of many organic topcoats.

ADDRESS
Nanomate Technology
3241 Keller Street
Santa Clara
CA 95054
USA
T: +1 4082008346

WEB
www.nanomatetech.com
Nanophos SA

DESCRIPTION
NanoPhos SA is a nanotechnology company which focuses on the development of innovative products that protect and waterproof common surfaces.

PRODUCTS
The company co-develop with Keraben LIFEKER®, a line of self-cleaning and self-sterilizing ceramic tiles. These properties of LIFEKER® tiles are provided by the use of the SurfaShield® coating technology developed by NanoPhos, which is activated simply by the energy of surrounding light (either sunlight or artificial lighting) without the use of dangerous chemicals.

TARGET MARKETS
- Construction and exterior protection

ADDRESS
PO Box 519
Science & Technology Park of Lavrio
Lavrio 19500
Attica, Greece
T: +30 22920 69312

WEB
www.nanophos.com
Nanopool GmbH

DESCRIPTION
The company manufactures ultra-thin nano layers, consisting of SiO2 molecules.

PRODUCTS
Nanopool GmbH develops SiO2 nanolayering technology (SiO2 = pure glass). Their product-literally “liquid glass” can be applied to virtually any type of surface to give the surface new properties. These properties include:
• Easier to clean
• Chemical-free cleaning – just use water
• Biostatic or anti Bacterial-dependent on variant used
• Abrasion resistance
• Stain Resistant
• Corrosion resistant
• Moisture resistant
• Protection from spills of acids, fats and oils
• Heat tolerant -40 to 450C
• UV Stable
• Free of nano particles
• Invisible and undetectable.

TARGET MARKETS
Nanopool GmbH’s liquid glass can be applied to virtually any type of surface to give the surface new properties including easier to clean, chemical-free cleaning – just use water, biostatic or anti-bacterial dependent on variant used, abrasion stain corrosion and moisture resistant, protected from spills of acids, fats and oils, heat tolerant -40 to 450C, UV Stable, free of nano particles while remaining invisible and undetectable.

ADDRESS
Nanopool GmbH
Zum Felsacker 76
D - 66773 Hülzweiler-Schwalbach
Germany
T: +49 68318902712

WEB
www.nanopool.biz
Nanops

DESCRIPTION
Nanops is a fully integrated European nanotechnology Company based in Belgium, and offers full service by combining in-house R&D, in-house production facilities, logistics and distribution to the benefit of the construction industry.

PRODUCTS
Nanops wide range of solutions goes from the delivery of nano raw materials to the production of finished products with, more in particular, coatings for steel and concrete structures. Different photocatalytic coatings, easy-to-clean coatings and coatings with a high chemical resistance are some of Nanops’ specialties.

TARGET MARKETS
• Anti-Graffiti
• Chemical
• Cleaning
• Corrosion
• Mechanical
• Thermal

ADDRESS
KOB NV
President Kennedypark 31 c
B-8500 KORTRIJK
BELGIUM

WEB
www.nanops.eu
nanoShell Ltd.

DESCRIPTION
UK-based nanocoatings company.

PRODUCTS
The nanoShell range of coatings are water repellant (or hydrophobic) coatings that can be applied to almost any surface.

TARGET MARKETS
• Glass Coating
• Metal Coating
• Stone Coating
• Wood Coating
• Solar Panel Coating

ADDRESS
3 Mary Seacole Road,
The Millfields,
Plymouth,
Devon, UK.
PL1 3JY
Tel: 0845 838 8648

WEB
www.nanoshell.co.uk
Nanosol AG

DESCRIPTION
Nanosol AG is a coating company specialized on the coating of medical devices. They were founded in September 1995 as a spin-off company from the Institute for New Materials (INM). Since January 2001 they have been based in Balzers the Principality of Liechtenstein.

PRODUCTS
The main field for the company is non-stick coatings, scratch resistant coatings and customer tailored developments of materials in the field of sol-gel chemistry. Organically modified silica is coated on glass, steel and aluminium. Sol gel based coatings solution produce a 1-4 micron thickness layer which is being manufactured for large-scale application.

The easy to clean surfaces is made by wet-chemical coating with subsequent heat-treatment. Organically modified metal oxide films form the base, reinforced by nano composite structures. The hydro- and oleophobic effect is obtained by perfluorinated organic molecule chains in the nano composite sol-gel coatings.

Application specific materials are synthesized by the proper choice of suitable starting compounds and process parameters. The resulting coatings consist of a three-dimensional cross-linked inorganic part (such as a silica network) combined with an organic part. The organic material acts either as a surface modifier (example: alkyl, phenyl) or as cross linker (example: acrylic, epoxy). The properties of such coating systems can be adjusted to obtain a wide range of glass-ceramic or polymer-like properties. The incorporation of nanoparticles into these materials significantly enhances the abrasion and the scratch resistance.

TARGET MARKETS
• Paint and Varnish Industry
• Pharmaceutical chemistry
• Medical devices and diagnostics market
• Inside and outside coatings of tubes and canulas
• Biocompatible coatings
• Easy-to-clean coatings
• Scratch resistant coatings

The company holds a patent for their nano composite sol-gel coatings. The coatings are compliant with existing European legislation and no hurdles are envisaged for the USA. The company do not license out the technology.

ADDRESS
Nanosol AG
Landstrasse 16
FL-9496 Balzers
Liechtenstein
T: +423 388 11 50

WEB
www.nanosol.com
Nanosys GmbH

DESCRIPTION
The company was founded in 2001 and produces super-hydrophobic, super-adhesive, super-hydrophilic and super-hemostatic nanocoatings.

PRODUCTS
NanoPerli is the company’s main product, a nanoscale chemical coating for various substrates and functions, for corrosion resistance, water repellency of raw, varnished, waxed, oiled and painted wood or wood materials, the hydrophobic treatment of sandstone, bricks, concrete and glass, which improve the adhesion of coatings on all types of plastics. The coating is also anti-adhesive.

TARGET MARKETS
• Wood
• Glass/Ceramics
• Mineral surfaces
• Textiles/Leather
• Anti Graffiti
• Flooring
• Plastics/Coatings
• Metal

ADDRESS
NanoSys GmbH
Dorf 31-32
p.o. box 135
CH-9427 Wolfhalden
Switzerland
T: +41 718900975

WEB
www.nanosys.ch
Nano-X GmbH

DESCRIPTION
Privately owned coatings company founded in 1999.

PRODUCTS
X-Clean Brand
- Easy-to-clean surfaces with nano-effect in the areas of protection against soiling for glass, ceramics and metal, protection against graffiti and demoulding aids, to name but a few
- Self-cleaning surfaces through the bionic effect or photocatalytic effect for interior and exterior applications
- Scratchproof and abrasion-proof coatings for plastics, metals etc.
- Multi-functional coatings to protect metals from corrosion
- Anti-fingerprint coatings for surfaces of stainless steel
- Catalytically active surfaces as coatings to decompose odors, soot or dirt
- Protective coatings to prevent dewing and fogging.

TARGET MARKETS
Industrial applications are mainly in automotive for oxide scale protection and easy to clean coating for automotive glass, as well as the steel industry.

ADDRESS
NANO-X GmbH
Theodor-Heuss-Straße 11a
D-66130 Saarbrücken-Güdingen
Germany
T: +49 681959400

WEB
www.nano-x.de
Nanto Protective Coating

DESCRIPTION
Nanto Protective Coating was founded in April 2010 with the goal to develop products such as innovative coatings and polymers based on proprietary nanotechnology. The NPC’s core know-how developed by the company can be used both as Industrial maintenance but also on new markets transferring and competing with major portfolio products in order to provide new products also to new structures. NPC has a very effective network of partners and collaborators that sustain R&D and product development activities, such as the Shenkar College of Engineering and Design in Ramat-Gan (Israel), the University of Bergamo (Department of Physics), the University of Trento (Department of Materials Engineering and Industrial Technologies) and dedicated Chemical Lab, such as NanoFab and Vega in Padoa (Nanotechnology Italian Cluster).

PRODUCTS
The patented NPC technology developed the effectiveness of nanoclays as barrier elements to corrosion (oxygen and humidity) and to thermal control. Nanoclay composites are currently generating a great deal of interest due to their potential cost effective advantages in barrier properties. Nanoclays are montmorillonite minerals which have been treated with compatibilizing agents, enabling them to disperse and orientate opportunistically into resins. In the last two years, NPC has been conducting technology research and focussed its efforts on the development of nanocomposites and in particular of nanoclay containing thermosets and thermoplastics. Starting from base research performed by international research partners, NPC has gone through all the product development value chain up to the production and commercialization of highly efficient anticorrosion and fire retardant coatings and polymers. All these sectors offering a Cost effective approach have unique Anticorrosion Properties and have already had a huge result, that is getting up to +30% with extended lifetime against corrosion. A first series of solvent based anticorrosion paint, called N.P.C. 100, is ready to market. This product can offer a unique cost effective solution to the problem of corrosion. N.P.C. 100, exploiting a patented proprietary nanotechnology, provides a barrier effect up to 30% higher than existing anticorrosion coatings. N.P.C. 100 series will soon be expanded to additional solvent system, water based system and powder based system. A part from the anticorrosion coatings which have some products ready to market and other very close to market, NPC is also active on a set of R&D activities which will provide the next series of NPC high performance coatings. This is to expand the product pipeline in order to support a continuous, strong and sustainable growth of the company.

TARGET MARKETS
Nanto Protective Coating, provides industrial innovative nano-coatings for the manufacture industry, marine, energy and lighting sectors and smart coating for cleantech sector.

ADDRESS
Veneto Nanotech ScpA
via San Crispino, 106
35129 Padova, Italy
Phone +39 049 7705500

WEB
www.nantopaint.com
nGimat

DESCRIPTION
nGimat manufactures engineered nanomaterials in the following areas: nanopowders, thin film coatings, and devices. nGimat’s NanoSpraySM Combustion Process technology enables synthesis of thin films and nanoparticles.

PRODUCTS
nGimat has used its CCVD process to deposit thin films with nanostructured surfaces that mimic the lotus leaf effects but in a controllable process that allows incorporation of other properties, such as transparency. On nGimat-coated glass, metal, or plastic surfaces, the water droplets are nearly perfect spheres.

TARGET MARKETS
nGimat is actively developing self-cleaning coatings for architectural glass, automotive glass, solar cells, space applications, and other specialty products.

ADDRESS
nGimat Co.
5315 Peachtree Industrial Boulevard
Atlanta
GA 30341
USA
T: +1 6782872451

WEB
www.ngimat.com
n-Tec GmbH

**DESCRIPTION**
The company is privately owned and involved in the development, production and sale of surface coatings in the nanoscale range.

**PRODUCTS**
The company produce easy-to-clean, photocatalytic, anti-fingerprint, anti-scratch coating properties for metals, glasses and polymers with automotive application as head lights, windows, felloe, varnishes as well as the vehicle industry in general. Main products are:
- x-photocat PSC: Photocatalytical self-cleaning and superhydrophilic coating for metals, glasses and polymers
- x-photocat PSCF: Photocatalytical self-cleaning and superhydrophilic coating with “Easy to Clean” properties for metals, glasses and polymers

**TARGET MARKETS**
- Sanitary equipment: Armatures made of steel, soap and paper dispenser, binds, doors
- Kitchen and household appliances: kitchen sink, exhaust ventilation, hearth blind, refrigerator, mixer, coffee machine
- Buildings: Doors, gates, door-handle, elevators, letter-box, entry-phone
- Metal cupboards and furniture
- Articles for daily use made of stainless steel, cooper, brass or bronze

**ADDRESS**
n-tec GmbH
Siemensstraße 13
D - 84051 Altheim
Germany
T: +49 8703989764

**WEB**
www.n-tec.de
Panahome

DESCRIPTION
Panahome Corporation is a Japan-based company primarily engaged in the housing business. The Company is involved in the basic design of housing under the name Panahome, as well as the manufacture, construction and sale of housing system materials.

PRODUCTS
The company produces KIRATECH tile for exterior walls that employ advanced photocatalytic technology.

TARGET MARKETS
• Construction

ADDRESS
1-1-4, Shinsenrinishi-machi
TOYONAKA-SHI, OSK 560-8543
Japan
Tel: +81-6-6834511

WEB
www.panahome.jp
Percenta AG

DESCRIPTION
Percenta AG was established in 2001, and went public in 2007. A 9 person team is based at the head office and work with a range of contractors across the world.

PRODUCTS
Percenta AG offers a wide range of coatings with protective, easy to clean, and photo catalytic properties. Their products contain nanoparticles primarily made of ceramics, glass and titanium dioxide to be used on materials such as wood, stone, glass, leather and metal. The mechanism and properties are similar to the Degussa TegoTop coating.

The company sells in bulk quantities. Currently there are over 200 products being researched. Large orders have been received from automotive companies such as Mercedes. Development work is carried out in collaboration with Max Planck, Franhoufer and 2 other chemistry laboratories. They are expanding business rapidly into Middle East, Africa and United States. The company business model hinges heavily on marketing and distribution. Water repellent coatings are the biggest cash cow for the company, mainly for automotive, bathrooms and sealants market.

TARGET MARKETS
Current applications range from anti-tarnish and self-cleaning coatings on:
• Glass: windows and glass panels, solar cells, shower cubicles, mirrors
• Synthetic Materials: synthetic glazing, diver’s and swimming goggles, motorbike windshields, helmet visors, ski goggles
• Wood & Stone: masonry, terracotta, wood, natural stones, marble
• Stainless Steel: kitchen, furniture, lights and door handles, music equipment
• Cookware
• Antibacterial cleaning and sealing
• Textile & Leather.

The company is targeting to introduce its products to a number of countries. The cost of the product is calculated based on costs per kilogramme of the base material, filling loss (2%), trading unit, seal closing device, labelling, outer packaging, packing. The product is processed directly from a 200-litre barrel or a 1000-litre container.

No patents on existing product. The majority of raw material patents belong to Degussa who supply. They are planning on patenting of 36 products in the pipeline for novel products such as golden ink for writing which has a niche market. One person is dedicated to dealing with the companies IPR issues worldwide. The company also licenses for manufacturing.

ADDRESS
Percenta AG
Gildestrasse 5a
D-24960 Glücksburg
Germany
T: +49 4631444080

WEB
http://de.percenta.com
PJI Contract Pte Ltd.

DESCRIPTION
PJI Contract is a specialist contractor for industrial polymeric floors, protective coatings, and linings.

PRODUCTS
PJI Contract Pte Ltd has licensed the patented TiO2 manufacturing process developed by the Singapore Institute of Manufacturing Technology (SIMTech), a research institute of A*STAR for the Delta Nano range of products.

TARGET MARKETS
• Exteriors

ADDRESS
29 Woodlands Industrial Park E2
NORDIX
Singapore 757461
Tel: (65) 6766 0900

WEB
www.pjicon.com.sg
PureTi, Inc.

DESCRIPTION
PURETi, Inc. is a privately held, US based company formed in 2004 that has developed, patented and commercialized what it believes to be the most advanced and cost effective set of environmentally friendly, photocatalytic surface treatments available on the world market today.

PRODUCTS
PURETi produces a water based solution that air dries to form an invisible, well adhered, ultra thin, long lasting coating that actively protects all surfaces to which it is applied from the buildup of any organic matter - including bio-film, bacteria, molds or fungi.

PURETi solutions have been tested by an EPA-approved independent lab and found to be non-toxic (fish can swim in the 99% water PURETi solutions with zero mortality) and free of any VOCs, semi-VOCs, or heavy metals. PURETi solutions have been tested by the National Sanitation Foundation and found to be remarkably effective in their self-cleaning and functionality. PURETi’s ability to rapidly and effectively decompose nicotine (the single best marker for smoke odor) has been tested and confirmed by a leading independent US testing laboratory.

PURETi
- Aqueous, amorphous, titania, film-former that holds nano particles (as small as 6 nm) of anatase TiO2 in a stable suspension
- High surface area of titanium dioxide particle
- Rate of photocatalytic oxidation is enhanced by increased surface area
- Mode of action may be the targeting of the cellular membrane by the hydroxyl radicals, thus increasing permeability, disrupting metabolism, waste excretion and membrane stability

TARGET MARKETS
PURETi products can be applied to virtually any surface, including buildings, signs, solar panels, sidewalks, outdoor furniture, holding tanks, boats, and planes.

ADDRESS
Pureti
261 Fifth Avenue
New York, NY 10016
USA
T: +1 2126855400

WEB
www.pureti.com
Quantiam Technologies, Inc.

DESCRIPTION
Quantiam develops and commercializes products based on Advanced Materials, Catalysis, Coatings and Surfaces for critical and energy-intensive applications in the Chemical Process Industries, Oil & Gas and Defense sectors.

PRODUCTS
The company produces nanocoatings for improving wear and corrosion resistance.

TARGET MARKETS
• Oil & Gas
• Defence & Aerospace sectors.

ADDRESS
Quantiam Technologies Inc.
1651 - 94 Street NW
Edmonton, Alberta T6N 1E6
Canada
Telephone: 780.462.0707

WEB
www.quantiam.com
Resodyn Corporation

DESCRIPTION
Thermal Spray Business Unit designs, manufactures and markets proprietary equipment for the application of advanced foams, protective and structural coatings for NASA, the military and a variety of industrial companies.

PRODUCTS
The company’s thermal processing technology is used to produce superhydrophobic and corrosion resistant nanocoatings.

TARGET MARKETS
• Military and commercial aircraft coatings
• No skid coatings on deck surfaces found on ships
• Bridge understructure corrosion protection
• Exterior protection of structures such as guard rails and signs
• Nano reinforced coatings for blast protection

ADDRESS
Resodyn Corporation
130 N. Main Suite 600, Butte, MT  59701
USA
T: +1 4064975254

WEB
www.resodyn.com
Saint-Gobain Glass

DESCRIPTION
Saint-Gobain is a world leader in the design, production and distribution of construction materials.

PRODUCTS
SGG NANO is a high performance coated glass with advanced energy efficient solar control and thermal insulation properties. This Advanced Solar Control and Thermal Insulation (low e) Glass is manufactured by deposition of multiple layers of highly specialized nano-metric metallic oxides / nitrides by a process of magnetically enhanced nanotechnology-based cathodic sputtering under vacuum conditions.

TARGET MARKETS
• Construction and exterior protection

ADDRESS
Saint-Gobain Glass India Limited
RR Tower 5, 3rd Floor,
Chennai - 600032
Tamil Nadu.
India

WEB
http://in.saint-gobain-glass.com
SunCoat

DESCRIPTION
SUNCoat GmbH engages in the production and sale of technical films. Its products include colored, light, awnings, banner, and transparent films, as well as vinyls and rotation-sieve-prints. The company offers whether, heating, and adhesive films for cars. It also provides UV-protect and self-cleaning films for glass fronts or shop windows, as well as films for printed banners, tarpaulins, and advertising posters. The company was founded in 2003 and is based in Zittau, Germany.

PRODUCTS
SUNCOAT’s heatstop is a 100-µm thick transparent self adhesive polyethyleneterephtalate (PET) foil with 12.5-µm thick transparent (transparency > 80%) nano coating which can reflect and absorb the sun’s ray and keep out the heat. The temperature of sealed box using SUNCOAT heatstop on the front glass window remains at 27.3 °C while the adjacent box without SUNCOAT heatstop is heated to 43.7 °C by the same light source in several minutes (see figure 1-B). Nanoparticles dispersed in the substrate materials are smaller than the wavelength of the light and so it is invisible. The functional nanoparticle (~25 nm) coating is transparent and shows excellent infrared (IR) absorption. Compared with the similar products from 3M which reflect 50% of the sunlight, SUNCOAT heatstop can only reflect 20% of the sunlight. However, its superior IR absorption property allows it to absorb 29% of total light. As a result, the SUNCOAT heatstop is able to match the performance (UV and IR protection) of a 3M product but with 30% lower in price. In addition, it also has an additional advantage that the coating surfaces won’t become wet by the condensation of water from the cooled air thanks to its IR absorption automatically warming up the coating surfaces.

TARGET MARKETS
Self-adhesive SUNCOAT heatstop is easy to handle and has widely been used for the heat protection of greenhouses, sun parlors, glass facades and roofs in industrial buildings. In addition to the sales in Europe, this heatstop product has been applied to the roofs of industrial plants in Mexico and China for providing more comfortable working environments and saving energy as well as cost.

ADDRESS
SUNCOAT GmbH.
Technische Folien Olbersdorfer Str. 11 02763
Bertsdorf-Hörnitz
Germany.
Tel: +49 3583 51 42 47

WEB
www.suncoat.de
Theta Coatings

DESCRIPTION
THETA produce and develop high performance nano-coatings based on patented soluble Metal Oxide Technology.

PRODUCTS
THETA technology produces super-smooth super-hydrophilic coatings. The technology facilitates doping uniformity unparalleled with other technologies.

TARGET MARKETS
Anti-bacterial, anti-pollutant and self-clean properties across the Steel, Glass and Ceramic sectors.

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CONTENT
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