

Finnish nanotechnology for machine builders



Introduction

Welcome to explore the Finnish excellence in nanotechnology and new materials. Nanotechnology will definitely be one of the opportunities to ensure the competitiveness of the established traditional industries during the globalization of the production.

This brochure concentrates on highlighting the expertise that Finnish companies, universities and research institutes have to offer specifically for the companies operating in the machine building sector.

The first part of the brochure concentrates on future materials and technologies that are not available yet, but are under research and will be available within 5–10 years time. The contact information to the experts of each topic is included.

The latter part of the brochure illustrates companies and products that utilize nanotechnology and that are already in the market and that might be interesting to the companies and workshops working in the metal or machine building industry.

The aim of this publication is to encourage companies to exploit the possibilities of new technologies as innovators in the machine building industry, to strengthen the competitiveness of established companies and to renew the machine building industry through the use of new materials and technologies.

The Finnish nanotechnology know-how is both deep and wide and therefore this publication is not meant to paint the whole picture, but to give an insight into the topic focusing on the know-how relevant for machinery. To find more about Finnish expertise in this area you can visit the following web sites:

www.nanobusiness.fi
www.nanoresearch.fi
www.findnano.fi

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Nanotechnology Cluster Programme

Nanotechnology Cluster Programme (2007–2013) initiated by the Ministry of Employment and Economy promotes nanotechnology based business in Finland. Nanocluster is a nationwide network reaching more than 90 % of all Finnish nano- and microtechnology related activities and stakeholders.

The mission of the Nanocluster is to foster the growth of Nanotechnology based business and to support implementation of nano and microtechnologies and future materials in Finnish companies.

More information:
www.nanobusiness.fi



Nanotechnology in Finland

Finland has invested actively in the development of nanotechnology since 1990s. Ministries, Tekes (the Finnish Funding Agency for Technology and Innovation) and Academy of Finland finance the development of nanotechnology in Finland.

Finnish innovation environment combines public and private sector. Almost 200 Finnish companies have commercial nanotechnology product (the number includes services), and if vision stage is included, 400 Finnish companies are involved in nanotechnology. Finnish Nanotechnology business is supported by research conducted in 170 groups both in universities and in research centers.

The turnover of Finnish commercial nanotechnology sector was over 300 million euros in 2008. In 2013 it is estimated to be 1.2 billion euros (source: Finnish Funding Agency for Technology and Innovation). Finnish companies with commercial products are successful according to the EU survey (NanoCom).

The spearheads of Finnish nanotechnology:

High class research & well established business:

- *Nanomaterials*
- *Nanosurfaces and coatings*
- *Microtechnology and sensors*
- *Diagnostics, pharmaceuticals, medical*
- *Photonics*
- *Aerosols*

High class research, to be commercialized:

- *Safety and metrology*
- *Modelling and characterization*
- *Nanoelectronics*
- *Nanocellulose*
- *Printed Intelligence*

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***Finnish nanotechnology
available in 5–10 years***

Coatings

Clean and easy-to-clean surfaces

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 ultra-violet 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 surface is done in accordance with the Lotus phenomenon in which the surface becomes a super-hydrophobic whereby water-based spray dirt does not attach to it and water droplets driven away clean the settled dirt particles on the surface. A superhydrophobic surface can be achieved when hydrophobic chemistry is combined with a suitable surface roughness.

Self-cleaning must always fit the circumstances and the effect of water washing. In addition to self-cleaning surfaces, there are so-called "easy to clean surfaces" that require at least some active cleaning.

Surfaces can be modified to become more permanently clean through many different technologies. These have been actively devel-

oped in recent years for a variety of materials and different applications. The high expectations for self-cleaning coatings, however, have nevertheless been unfulfilled. Easy to clean coatings, on the other hand, have achieved obvious progress in many areas. Antimicrobial and frost-free surfaces that concern this subject area are treated separately later.

Application target

Improvement in the appearance of machinery and equipment, hygiene and corrosion resistance in different environments. Machinery and equipment operating in dirty process conditions. Energy technology equipment; wind generators, solar cells and solar collectors. Sensors, measuring devices, packaging, and 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. 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 currently being vigorously studied.

MATURATION RATE	
Now	Commercial applications using photocatalytics and Lotus surfaces on different constructed environment surfaces, as well as water and air cleaning.
in 5 years	Easy to clean surfaces for a wide range of materials, developing solutions for demanding process industry applications, as well as for the food industry. Maintaining or restoring functionality in long term use.
in 10 years	Expanded industrial use in different applications, for example, self-cleaning surfaces in interior spaces.

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Surfaces

Antimicrobial coatings

Antimicrobial coatings can be done in different ways. The most commonly used solutions in nanocoatings are mainly based on silver and titanium dioxide (TiO₂), also there are a number of reports on the antimicrobial properties of carbon nanotubes. Leachable antimicrobial chemicals such as silver seek to control deadly chemical releasing bacteria. With the exchange of substances less harmful to the environment and by controlling the rate of release, it is possible to develop more environmentally friendly alternatives. TiO₂-based antimicrobial coatings are based on photocatalysis and its ability to dissolve organic "dirt."

The next step in the study of antimicrobial surfaces is the development of reactive coatings. In this case, biocides are released only when needed, for example, when the surface coating is anchored to microbial flora. The coating actively reacts to the chemical or physical presence of the flora. Technology is being developed for different applications.

Antimicrobial surface modification without a toxic environmental effect has been used, for example, in the silver coatings of refrigeration equipment. Coatings of this type do not kill the

flora, but prevent or very strongly slow their growth on the surface. Development is strong in applications demanding a high hygienic level such as in the food and health care sectors. In addition, completely non-toxic coatings and surface structures in which the microbes do not attach are being developed.

Development is underway on super slippery and clean surfaces such as in boat flora blocking coatings. With nanotechnology, satisfactory results have been reached for faster vessels, and development continues for lower speed targets. Together with the easy to clean surfaces, antimicrobial coatings represent a very large and attractive development target.

Application target

Application targets are new material technical solutions that reduce or prevent the adhesion of bacteria and other organic flora in healthcare, pharmaceutical and food industry equipment. Antimicrobial coatings can also be used on flow surfaces to prevent biofouling and reduce biofouling induced corrosion. In addition, indoor and humid areas, microbial growth can be limited by surfaces that are easier to clean.

MATURATION RATE	
Now	Used in of the controlled release of biocides, non-toxic coatings for household appliances.
in 5 years	New antibacterial surfaces for different applications. Using release control, the lifetime of the coating increases.
in 10 years	Industrial applications in a wide range of industrial sectors. Non-toxic coatings on underwater parts.

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Coatings

Frost-free coating

Ice that accumulates on surfaces in cold regions is a big problem in different vehicles on land, at sea or in the air. Also in numerous other machine construction and structural technology applications, surface freezing can cause malfunctions, such as in antennas and wind turbine wings. Ice buildup can also be blocked by means of nanotechnology by changing the surface so that it will not stick or freeze shut. In this case, water drops from condensation, rain or spills are removed from the surfaces or collected into structures. Anti-icing coatings are under development for several applications. The machine building industry in addition to the

maritime, aviation and construction industries are interested in new options. In addition to coating structures based on superhydrophobicity and passive low surface energy, there are electromagnetic solutions that also prevent ice from sticking, such as low power consuming and lightweight actuators used on airplane wings. Actuators are presented in more detail later in this report.

Application target

The application targets are the exterior surfaces of all kinds of machinery, equipment and structures to prevent ice accumulation.

MATURATION RATE	
Now	Poorly used in special applications.
in 5 years	First frost reducing applications.
in 10 years	Applications in use.

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Coatings

Wear resistant coatings

Surface hardness and the wear resistance of materials can be significantly improved through a thin surface coating making the base material harder and improving the wear resistance of the surface. These coatings may be different kinds of ceramics, composite materials, or diamond-like carbon coatings. 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. Great developmental strides are expected. Together with friction management, machine and engine technology are especially large targets of developmental activity.

Application targets

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.

MATURATION RATE	
Now	Sol-gel based wear-resistant hard coating exists primarily for transparent plastics. Similarly, machine building surface materials can be made very durable through, for example, thermal spraying.
in 5 years	Sol-gel-based and other nanostructured coatings will improve and their uses will increase.
in 10 years	There will be a number of uses for nanotechnology-based, wear resistant coatings.

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Coatings

Coatings for demanding conditions

With thermal spraying, hard and wear resistant coatings can be manufactured, for example, for demanding applications. In this method, the starting material is often a powder form that is melted at high temperature and sprayed over the item to be coated. The coating is formed by melt droplets hitting the item surface through which the surface structure typically becomes lamellar. With the new spray technology and even better starting material powder consumption, the coatings can achieve an even closer and more controlled structure. At the same time, both the surface quality and the chemical composition will be managed even better.

Using the new CJS (Carbide Jet Spray) method that produces nanostructures through spray-drying from water-soluble materials, the nanostructure produced from thermal spraying powders can be maintained even after spraying. Using water-based processing, the agglomeration of nano-powders can be avoided by

handling when dry. In addition, the powder composition can be tailored very carefully and the powders made particularly homogeneous.

Nano-powders can be condensed into fixed pieces also through the method known as Spark Plasma Sintering (SPS), which allows for the rapid compaction of powders at a lower sintering temperature. The rapid process produces lower structural growth than the traditional sealing methods, allowing the nanostructure to be better maintained. The method is suitable for compacting nano-sized, meta-stable and amorphous powders close to theoretical density.

Application target

The application targets of methods using thermal spraying of new nano-powder are nearly all thermal spraying targets in which improved mechanical and corrosion resistant properties from the coating and better surface quality are needed.

MATURATION RATE	
Now	WC and Cr ₃ C ₂ powders produced. Higher performance of the first nanostructured coatings indicated in laboratory tests.
in 5 years	Improvements in the surface quality and features of the coating. New coatings established for applications. SPS method in industrial use.
in 10 years	New commercial applications of nanostructured coatings. Tailor-made material solutions, such as functional TRAPPI structures, established for applications.

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Coatings

Self-healing coatings

Self healing coatings are materials whose structure is combined with the ability to repair the coating resulting from mechanical damage, either for aesthetic or operational reasons. Self healing materials are inspired by natural biological systems with the ability to heal themselves after injury or wounding. A self healing surface may, for example, remove scratches reducing the shine from the paint surface or restore and repair damage to the technical properties of the surface against the corrosive stresses of the environment.

Research on the self correction of aesthetic damage has focused on repairing damage occurring before the product is used. In this case,

the operating time of the self-repairing feature is limited and thus more manageable. Research on the self correction of technical defects is clearly focused on the reversibility of damage during the use period of the product. The idea of self healing is not new, but new ways to create functional materials and nanotechnologies can bring it to fruition.

Application target

Scratches during the transportation, storage and installation of products cause great economic losses. The use of a self healing coating on the product surfaces combats this. Future application targets can also include the external coatings of boats and ships.

MATURATION RATE	
Now	Self correcting car paint against transport damage.
in 5 years	Self correcting coatings against aesthetic damage used against transport, storage and installation damage.
in 10 years	Significant improvement for corrosion protective coatings.

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Coatings

Friction reducing coatings

Friction causes energy loss and increased component wear in machines and devices. A large part of the produced energy is used to overcome friction and another on the replacement of worn parts. The functionality, reliability and the life of the friction pairs of various machine parts and tools can be improved through the use of new technologies such as diamond and nano-composite coatings.

Application targets

As a result of the nanoscale customization of contact surfaces, there is a reduction in the sliding and adhesive wear and friction of the material pairs. The same solutions can also be used for different detachment surfaces.

MATURATION RATE	
Now	Research and development.
in 5 years	Tailor-made solutions for various material surfaces.
in 10 years	Large-scale industrial applications in various industries.

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Coatings

Heat transfer and condensation surfaces

Various types of heat exchangers are used in numerous industrial processes, machinery and equipment. Heat exchanger activity affects, inter alia, energy efficiency. Refrigeration and air conditioning particularly consume a lot of energy. The soiling of heat transferring surfaces reduces the heat transferring coefficient, increases flow resistance and impacts potential corrosion problems. Nano-coatings are able to affect contamination and the behavior of fluids on the heat exchanger surfaces. Optimally, a

functioning heat exchanger enhances energy recovery and reduces costs and environmental impact.

Application target

Hydrophobic and hydrophilic surfaces (including repellency or adherancy to other liquids) in air conditioning, energy technology equipment, fuel cells, dispensers and condensers, and in prevention of ice formation and so forth.

MATURATION RATE	
Now	Individual experiments done.
in 5 years	Tailor-made heat transfer surfaces and controlled condensation surfaces exist for a variety of materials.
in 10 years	Optimized and managed solutions in energy technology components and in the process industry.

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Coatings

Flow surfaces

Coatings and surface treatments can reduce friction between variety of liquid and solid materials at the flow surfaces. In particular, fouling caused by micro-organism and contamination in heat exchangers, piping, and boats and at the submerged surfaces of boats and ships increase drag and cause corrosion.

Application target

Liquid and solid material flow surfaces are used in, for example, piping, macroscopic applications, dosing and microfluidics. Flow friction reduction, proportioning refinement, and keeping surfaces clean.

MATURATION RATE	
Now	Research and development.
in 5 years	Tailor-made low friction surfaces for different fluid flows. Improved accuracy in different proportioned surfaces.
in 10 years	Industrial applications on flat surfaces, and developed solutions for pipelines.

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Nano composites

High-strength and lightweight plastic nano composite

The strength of thermosetting plastics and thermoplastics can be increased with the addition of nanoparticles, fibers or fabrics. A nano- or microporous structure may also lighten the material. Better chemical resistance, less water vapor and gas permeability, higher heat tolerance and mechanical strength can be achieved by mixing a polymer such as nano clay, which also improves fire protection. There are a countless number of combinations of plastic matrices and filler material mixed into the plastic matrices that can improve mechanical properties.

The biggest challenges in the use of nanotechnology are related to the processing of nanomaterials, which is challenging in industrial processes because of the strong agglomeration tendency. The benefits of nanoparticles are best brought forth if the nanoparticles can be kept apart from each other and can be dispersed in a controlled fashion during processing, for example, while mixing them in plastics. In this case, even a small amount (less than 2%) of nano-filler can bring about drastic change

of the plastic material. Nano-filler dispersion technology and chemicals promoting adhesion to various plastic matrices are being actively developed.

The most common properties of plastic nanocomposites are: lower viscosity, increased operation temperature of the product, improved mechanical properties, increased stiffness and hardness, light weight and dimensional stability, improved wear resistance, improved surface finish, improved barrier properties, fire resistance, chemical resistance, electrical conductivity, optical properties, and easier recyclability.

Application target

Application targets include various automotive plastic composite parts, shock-resistant composite materials, sports equipment, good moisture- and fire-resistant properties such as for the protection of electrical connectors. Stronger plastic composites may allow for the streamlining of the structure.

MATURATION RATE	
Now	Nano enhanced thermosetting plastics and thermoplastics for the general purposes of strength and stiffness. Generally, basic fillers, including "custom" fillers.
in 5 years	More functionality combined with traditional features, such as wear resistance, stiffness, and barrier properties. Vibration and noise suppression can be developed with new lightweight construction. New nano-enhancement such as nano-cellulose established for applications.
in 10 years	Nano composites for customized features. Nano-filler dispersion is much better industrially managed. Nano-porous, transparent, lightweight structures are produced.

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Carbon based materials

Nanodiamonds in tribological contacts

Nano-Diamonds belong to the carbon nano-material family, whose unique physical and chemical properties have attracted considerable interest in recent years in countless applications. Nano-Diamonds can be manufactured, for example, by the plasma-assisted chemical on a gas phase coatings and by the explosive

method in the detonation chamber.

Application target

Nano-diamonds applications include material crushing and polishing, friction reducing engine oil additives, solid lubricants used in the metal industry and electroplating electrolyte additives.

MATURATION RATE	
Now	Features demonstrated, but not well characterized. The first commercial nano-diamond-based lubricants placed on the market.
in 5 years	Diamond-based nano-additives in some commercial applications.
in 10 years	Diamond-based nano-additives in many commercial applications.

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Carbon based materials

Nanostructured carbon based coatings

Nano-materials consisting solely of carbon form their own interesting group, for which future expectations are high. Carbon black is the most familiar and quantitatively clearly the most used nano-carbon at the moment. Carbon black is used in several applications such as tires, inks and conductive plastics. Other carbon nanomaterials include nano-diamonds, spherical fullerenes, nanotubes, nanobuds (nanotube and fullerene composite

structure) and graphene (one atomic layer thick carbon sheet).

Application target

Nanostructured carbons can be used for, inter alia, the improvement of the mechanical properties of composite materials, the improvement of different battery and cell properties and in the manufacturing of flexible and transparent electrodes.

MATURATION RATE	
Now	Tribological tool and component coating.
in 5 years	Carbon based coatings used as bio-compatible coatings.
in 10 years	Functional applications, such as sensing and Haptic surfaces.

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Active materials

Sensor and actuator materials

Ever more types of materials and technologies are increasingly coming into use in which reactive sensors actuator properties are combined and utilized for a variety of environmental conditions. Nanotechnology can improve the sensitivity of sensors and actuators in certain applications by strengthening the functional properties of materials such as sensitivity to gases, chemicals, biological substances and different pollutants. Nanotubes and wires, nanoparticles and quantum dots allow the sizes of sensors to further reduced. The larger significance of nanotechnology in the development of sensors and actuators in the near future is their integration into the other structures, in which case they will be an integral part of some bigger component. Typically used in a lot of sensors, such as pressure and acceleration sensors, MEMS technology dominates the market and is likely to maintain its position over the medium term.

Application target

Clothes that react to the weather, information system user interfaces, physiological monitoring, drug delivery, construction, engineering and automotive technology. In addition, different detection and security solutions, and real-time

detection of various chemicals and biological molecules and components.

Over a longer time period, the use of nanotechnology in sensors will increase, and nano-scale processing will often be required when traditional production methods are not sufficient. Examples include the manufacture of nano-fibers measuring pressure, the use of nano-porous silicon as a gas sensor, and the use of self-assembling molecular layers for bio-sensing. Currently, the use of nanotechnology in sensor technology is still relatively rare in commercial applications. New sensor nanotechnology is becoming particularly used for the immunological sensing of biological phenomena and semiconductor sensors. Nano-technological material solutions may find their place in MEMS applications in 5 years. The actuators in traditional electric motors, pneumatic and hydraulic systems will retain their place for a long time. The proliferation of nano-technology-based actuators is further concerning applications such as sensing nanomaterials. Nanostructured piezomaterials, electronics and magneto rheological materials are typical applications. These can for example actively dampen vibrations and therefore noise.

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Active materials

Display surfaces and adjustable light transmittance window surfaces

Color-changing windows or surfaces can be implemented through electro-chromatic materials, which reversibly change color and light transmittance through an electrical field. These materials can be controlled by a few volts, and the amount of light transmission can be automated through sensors. Light transmission can be achieved through the use of electrochromism (EC) in addition to Polymer-Dispersed Liquid Crystals (PDLC). Electrochromic materials are used, inter alia, to adjust the darkness of the windows and automatically darken car mirrors. The technology can be used to regulate incoming light and heat amount as the need arises.

Thermo-chromic materials, in turn, change color according to temperature change. Thermo-chromic pigments and liquid crystal devices can be mixed into plastic so that the choice of pigment can affect the color change in the temperature regions. Using a combination of more pigments, many degrees of color change

can be done. With thermo chromatic membrane materials, window transparency can be adjusted, but the transparency disappears into cloudiness when a level change is activated.

Application target

Electrochromic materials can be applied on windows, when the incoming light and heat amount is to be controlled or automated. The electrochromatic window is typically always transparent, although it also can become darker until opaque. Using PDLC technology and thermo-chromatic materials, the space between opaque, cloudiness and clarity can be regulated, whereby the transparency can easily be lost through the limitation of light transmission. Enlightening can be done using polymeric film materials on large, smooth or curved surfaces, which thereby produces glare-free light. As the technology advances, for example, a wall surface can be equipped with OLED technology to allow a high-resolution screen.

MATURATION RATE	
Now	Electrochromic materials applied in cars and airplanes. For some building windows, electrochromic solutions have been implemented. In display technology, the first organic light emitting diode (OLED) based displays come to market. The current OLED screens have a service life of about 5000 h.
in 5 years	The development of OLED technology will bring large OLED televisions to market.
in 10 years	OLED displays can be made for HD-resolution large screens. OLED display life expectancy will increase so that it does not become a sales obstacle. OLED technology will replace plasma and LCD technologies. Energy glasses that change under a controlled reflection coefficient will be already commercially available (mirror/window).

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Active materials

Oscillation damping

Using functional materials, an external impulse such as a mechanical load, temperature, light, electrical or magnetic fields give rise to any deformation, color change, for example, or a change in conductivity. Functional material designed for a particular conditions react in the desired way when the conditions change. New materials and control technology can be combined to produce advanced solutions for mechanical vibration control. Future vibration-absorbing structures using functional materials

can be lightweight, rigid and have good damping characteristics at the same time.

Application target

Active materials can be utilized in numerous applications such as sound and vibration control. Examples of active vibration damping for suitable materials include electrically controlled piezo-electric materials, magnetically-guided magneto rheological fluids and elastomers, as well as thermally controlled memory metals.

MATURATION RATE	
Now	Laboratory scale demonstrations performed at the research and development level completed.
in 5 years	Commercial passive audio and oscillation control solutions are stabilized.
in 10 years	Commercial adaptive audio and oscillation control solutions are stabilized.

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Active materials

Embedded sensing

Embedded sensors and other electronic components can be manufactured with high accuracy directly onto the product surface without masking using the so-called Direct Write (DW) methods. The methods are based on both thermal spraying and liquid dosage. They are suitable for use in three-dimensional pieces and structures, as well as in a variety of materials and material combinations. Using the micro-plasma-based

thermal spraying technique, high-quality wire and insulation materials can be produced for a different substrate without the need for post-processing.

Application target

Multi-functional structures, heat and strain gauges, antennas, electronics components. Encapsulation of printed electronics such as inside of transparent thermoplastic plastic.

MATURATION RATE	
Now	Manufacture of the sensor component to the surface under laboratory conditions.
in 5 years	Implementation of first simple sensors for industrial production: temperature sensors, distortion sensors and sensors for stretching.
in 10 years	Commercialization of complex embedded sensor structures, including energy generation systems.

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Active materials

Invisible conductive nano-films

Highly conductive transparent thin films will have a lot of applications in electronics. In the future there will be an increasing need, for example, for portable flexible displays and solar panels. Transparent and flexible film can be used in these as electrodes. Reliability and consistency as well as manufacturing simplicity and the price of display

screens are crucial for the rapid growth of the display application.

Application target

The main application targets for conductive thin films are computers, phones and television touch screens, electronic paper, solar cells, OLED lighting and sensor applications.

MATURATION RATE	
Now	Demonstrated in the laboratory.
in 5 years	Applications include in touch screens, solar panels and printed sensors.
in 10 years	Enhanced features of materials, manufacturability and low cost will allow broad range of applications, including in solar cells.

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Materials mimicking nature

Nanocomposites

Naturally occurring materials and structures are the inspiration for materials mimicking nature (or biomimicking materials). For example, the light weight, stiffness and strength of the honeycomb structure; the light weight and elasticity of the web used in a spider web; the mechanical properties of mollusk's pearl, and the optical characteristics dependent on viewing angle of a pearl, the flow resistance of shark scales and the adhesion reduction feature of micro-organisms.

Application target

Using new technologies, the mechanical properties of earlier nanotechnology can be made significantly better in an environmentally friendly, inexpensive and fast manner. Using paper production techniques or by painting from roll to roll, nano composites and biomimetic surfaces can be made that mimic the shimmer of a pearl or silk.

MATURATION RATE	
Now	The first version works in the laboratory. Companies are being outlined, products identified, properties optimized. Domestic financing sought.
in 5 years	Small or medium-sized enterprise set up, the first products on sale: mobile technology, laptops, OLED encapsulation, barrier applications, thermal insulation.
in 10 years	Hopefully, the company expands and makes a commercial breakthrough.

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Materials mimicking nature

Flexible dye solar cells

Solar energy is a great resource whose exploitation has been limited so far, but whose importance in energy production will increase. Dye sensitized nanostructured solar cells (DSSC, DSC or DYSC), or Grätzel cells are thin film solar cells to imitate photosynthesis. The cell is formed from a porous TiO₂ nanoparticle layer that is surrounded by an electrolyte solution and covered in a dye which is in between a transparent electrode and a metal electrode.

The dye-cell absorbs sunlight and acts like green leaf chlorophyll. Cells can be made into a flexible film from inexpensive materials, which makes it attractive, although its efficiency is worse than the best cells made from more expensive materials.

Application target

Transfer of solar energy into electricity: machinery, equipment, and energy management.

MATURATION RATE	
Now	Small prototype.
in 5 years	Pilot line.
in 10 years	Production line.

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New applications

Surface and colloid science

Surface and colloid science separates the surface properties affecting the bulk material (colloid), although the proportion of the surface feature grows with the addition of high resolution. In nano-science, such a clear division of characteristics is not made, but attention is focused only on finer sized fractions, where surface properties are predominant (nano-effect).

Application target

Colloid science is applied in all technology areas. A particularly prominent place for it has been in bio-, electronics and composite material technology.

MATURATION RATE	
<i>Now</i>	Surface and colloid science (especially chemistry and physics) is 150–200 years old, but through what is known as nanoscience the development of the model systems and applications has gotten to a settled, research policy acceptable stage.
<i>in 5 years</i>	Since most technologies are emerging for the miniaturization of information and properties, it is clear that surface and colloid science, for example, under the name of nano-science, will preside over a large area of technology applications.
<i>in 10 years</i>	It is expected that miniaturization will increasingly move to the molecular level. In this case, technologies are increasingly utilizing molecularly produced and/or nano-engineered structures, where both the molecular and surface characteristics are predominant. An example of this is another new surface and colloid science branch, i.e., sol-gel science. In this, the characteristics of nano-structures are managed in the synthesis stage. In addition to Zeolite chemistry, specific surface properties can be focused onto large pore surfaces or onto the outer surface of a nano-material.

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New applications

Nanoparticles for various application targets

Nano-sized particle shaped materials have tremendous applications in a wide range of conditions from self-cleaning coatings to suntan lotions and drug administration. Layered and shell structures, nano-balls as well as various chemical and particle dopings that were achieved using advanced manufacturing techniques further increase the opportunities for use in the future. Particles can be prepared, inter alia, using pyrolysis, sol-gel and emulsion technology through which the composition as well as the particle size can be controlled.

Application target

Nanostructures, such as new sensor solutions, photo catalytic particles, nano-composites, made from oxide, mixed oxide and hybrid materials, and metal particles: self-repair, anti-bacterial and corrosion protection. In addition, multi-functional magnetic nanoparticles can be used, for example, in the following targets: inorganic magnetic support materials, magnetic photocatalysts, magnetic fluids (ferrofluids) containing nanoparticles, magnetically controlled waste water treatment and the controlled release of functional materials.

MATURATION RATE	
Now	Photoactive particles, mixed-oxide production. Antibacterial SiO ₂ doping powders produced by the sol-gel method.
in 5 years	The controlled release of functional materials from microcapsules.
in 10 years	Several commercial applications. Strong and hard nanocomposites, new electro-ceramic applications.

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New applications

Multilevel-model assisted design

The development of new construction materials is always a complex equation of crossing interactions affecting the physical and chemical phenomena through to the level of the material's behavior on the microscopic level. In addition, material processing always significantly impacts the formed material's properties and behavior in different operating environments. Modeling knowledge has greatly increased in the last decade, with the help of the growth in numerical calculation capacity and the development of commercial multi-level and multi-physics software. Nevertheless, material models are still made mostly in isolation from each other at various levels, either using models at the atomic level (quantum mechanical, molecular dynamic) or at the mesoscopic/macroscopic level where the coupling of the physical mechanisms at different levels is weak. Also, the simultaneous

observation of the mechanisms and phenomena at different levels when aiming for a specific property is often left to little notice. These do not maximally support the effort to develop a deep understanding of new materials.

Application target

At present, new and growing user requirements for structures and components will keep the need ongoing to develop more sustainable materials. Moreover, the need to truly optimize material sustainability is the latest feature required by users in material development. The traditional way of developing materials, in isolation at different levels as well as through modeling and experimental research, is ineffective when considering the opportunities served by multi-level modeling and processing of the properties of materials in systematic design as well as property-specific optimization.

MATURATION RATE	
<i>Now</i>	Understanding of material damage on the basis of modeling.
<i>in 5 years</i>	Optimization of the Processing-Structure-Property usability chain (PPSP) and linkage to the material's development on the basis of modeling.
<i>in 10 years</i>	Closed-loop material multiscale modeling and the direct linking of material processing to the material's usability.

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***Finnish nanotechnology
available now***

Adaptamat

Adaptamat focuses on developing and manufacturing NiMnGa based Magnetic Shape Memory (MSM) Alloys. MSM materials are functional and smart metals with several properties for actuators, positioning and sensor technology. Adaptamat has built several devices to demonstrate the MSM alloy's capability. Devices such as Vibration Energy Harvester, position sensors and actuators are being made.

Main properties of the MSM alloy are:

1. Villari effect – is used to make sensors and vibration energy harvesters. When external force presses and elongates MSM material placed in magnetic field the magnetization field is changed proportional to element's length.
2. Magnetic shape Memory effect – for actuators, grippers and microfluidics. Material elongates/compresses 6 % of its length in magnetic field (proportional to the field strength).
3. Proportional change of resistance and per-

meability – for sensors. Resistance (and permeability) over the length of MSM element is proportional to elements length.

4. High Temperature Shape Memory (HTSMA) alloy. Material can be formulated for High Temperature SMA applications all the way upto to 400 Celcius

5. Inherent holding power in power-off mode (grippers and actuators)

Adaptamat is Helsinki Finland based manufacturer of MSM alloys with international and very experienced group of researchers and application developers. As a materials company Adaptamat is interested in cooperation with end-application holders.

Below pictures show MSM based vibration energy harvester, displacement sensor and actuator and some MSM elements.



AdaptaMat

Adaptive Materials Technology – Adaptamat Ltd.
Magnetic Shape Memory (MSM) Alloys – smart metal alloys
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Ceratul® – new material for machine builders

Conventional plastics and polymers cannot withstand high temperatures without melting, burning or otherwise becoming destroyed. Polymer Ceratul® adhesives and related products are new material solutions for machine building applications which require high temperature durability or fire safety combined with lightness.

As electrically insulating material, Ceratul is also suitable for applications where insulation must be part of the machine. Using additives, anti-static properties may be added into the products, such as in conventional plastics.

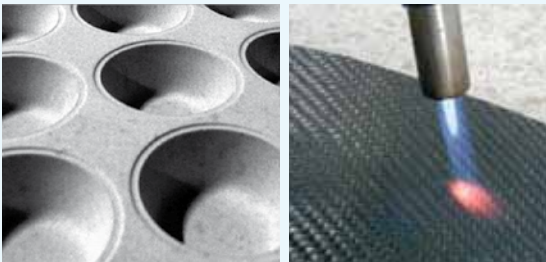
In places where temperature and humidity level changes are large, breathable Ceratul films can be used to protect mineral wool and foam-based insulation materials, for example, against

dirt, dust or heat or so that the moisture is not able to reach the structure as condensation. The structure remains healthy and functional, without the problems caused by humidity.

Ceratul products are non-toxic and environmentally friendly materials.

Ceratul products for machine builders:

- Ceratul resins: Liquid resins and adhesives for the manufacture of high temperature and fire-proof components.
- Ceratul Skins: Fire/heat films for fireproofing or for the coatings of porous materials.
- Ceratul C-pregs: Self-adhesive, heat-activated, non-woven fabrics and papers for heat-resistant structures simply and cost effectively.



Ceratul®

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Cerafone® – polymer insulators

Cerafone® foams, based on the unique ceramic Ceratol® adhesive technology, have been developed to serve as high temperature insulation solutions for applications in which greater stiffness that is achieved by mineral wool is required without compromising heat resistance.

Cerafone® foams are the world's lightest non-combustible ceramic insulation materials. The insulation can be supplied as separate chemical components or as finished insulation on a customer specific basis.

Micro and nano-porous material is suitable for use in the manufacture of a variety of fire-proof machine parts, including enclosures, feedthroughs, insulation panels and unit specific insulation. The key features include non-combustibility, light weight and good heat resistance properties. The ceramic two-component system provides versatile design possibilities, for example, in compression molding.

All Cerafone®-materials are non-toxic and environmentally friendly.



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Oy All-Plast Ab



Oy All-Plast Ab has invested heavily in the development of new raw materials and production technologies that are based on unique properties of new natural fibers. This development work has taken place in cooperation with domestic as well as European research institutes, for example, TKK, VTT, TTY, SICOMP, KTH, KCL have all been involved in development projects.

An important feature of natural fiber materials is, for example, that they have small thermal expansion in all directions, whereby they can be easily integrated with inserts which together with the traditional, e.g., fiberglass-hardened plastics easily cause twisting and breakages due to inner stresses because of the large thermal expansion differences between the plastic product itself and the insert.

An example of a new raw material is bio-based PLA-natural fiber composites, whose nano-cellulose content makes it extremely strong with a very small thermal expansion. The material has been developed in its own TEKES project, and as a joint EU project coordinated by All-Plast, and the brittleness/workability problems in injection molding normally associated with working in PLA have been successfully resolved. Similarly, using new production techniques, mirror surfaces and homogeneous spark surfaces for natural fiber reinforcements can be made up to a 40 percent load setting. This eliminates the surface quality problem normally associated with the use of natural fibers.

Another priority for All-Plast has been stone-based materials, which have achieved good dimensional accuracy and thermal conductivity, as well as good fire-resistant properties. Combined with good wear resistance, these materials are ideal, for example, for the racks and frames of various machinery and equipment. Essential benefit of all of the natural fiber-based and stone based materials is the diverse versatility for various purposes. At the same time, they provide the user with a competitive sustainable development option, which will continue to become a more important selection criterion for end-users.

Hybtonite® – carbon nanotube reinforced epoxy

Amroy Europe Oy develops and manufactures resins for the coating and composite industries. The company invests heavily in nanotechnology-based specialty resins, where it is the world's market leader. The company's top product is a carbon nanotube-strengthened epoxy Hybtonite®. It is used in the wings of wind turbines as well as in the sports, boating and racing products, and also in the paper, electronics and construction industries.

Hybtonite® is a hybrid material, namely, epoxy strengthened using carbon nanotubes in which the nanotubes chemically attach both to each other as well as to the epoxy matrix. Strong covalent bonds arise between the carbon and epoxy in the fabrication process, and the end result is an epoxy that is 20 to 30% more firm than conventional reinforced plastics. By varying the amount of carbon tubes, the

mechanical, thermal, and electrical properties of Hybtonite can be modified, as necessary.

Hybtonite® epoxy is available in many different grades, suitable for many needs. The latest innovation is Amroy's EPOBIOX™. It is a liquid epoxy system made of 70% natural oils, such as pine oil. The wind turbine industry is Amroy's largest customer segment.

Amroy's partners include:

- Bayer (Baytubes, Bayer MaterialScience)
- CompoTech
- Advanced Marine Coatings
- Baltic Yachts
- Lettmann
- Exel
- Peltonen
- Warrior Hockey Finland
- Easton

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EPOBIOX™

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Genano – air cleaning solutions for the air purification of machine shops and metal industry and also for the overall improvement of energy economics



*Genano 1000 air purification unit,
air volume approx. 7200 m³/h*

Genano Technology[®] fulfills the requirements of a new generation of air purification technology. Our air-cleaning devices protect the premises, workers and production processes from harmful impurities. Genano Oy's mission is the improvement of work productivity through good quality indoor air. Our solution offerings can also improve the energy efficiency of the site and bring cost savings. We want to increase people's well-being at the workplace and to enhance production through particularly clean room air.

Our core competence is to clean the interior air of ultra-small particles even to nano-meter scale size. Our technology efficiency has been studied at several prestigious research institutes such as VTT, Finland Institute of Occupational Health and LNE in France (Laboratoire National de Métrologie et d'Essais).

Genano Technology[®] is based on an electrical charge and ionic spray and does not use fiber filters in purification. Purification unit pressure losses are very low (2 - 3 Pa) and the unit cannot become blocked. Thus, the purification precision and the clean air output will remain at a precise level continuously without the need for filter change, which is necessary in solu-

tions based on fiber filter technology. Thus, the maintenance and operating costs of Genano air purification units are low. Genano Oy's main customer target groups are industry, public sector health care and property maintenance. The target is either self-made air pollution (e.g., quartz dust and welding fumes) or the removal of ensuing problems concerning fixed property (mold, fungal spores and VOC gases).

Genano 1000 series stationary mounted air purification units

Genano 1000 series mounting solutions are designed for production environments in which the work produces large quantities of air pollutants and the air volumes to be cleaned are large. Typical impurity producing processes include sandblasting, welding, cutting and grinding. The particle sizes produced are, for the large part, nano-sized.

Genano 1000 indoor air purifiers recycle the interior air, and they are implemented with exhaust and supply channels that enable high-precision air purification. As the purified indoor air is returned the system offers an opportunity to reduce the volume of replacement and exhaust air which means that the thermal energy possibly generated in the production can be used better. The Genano 1000 air purification units can be used to get rid of interior air problems using a different multiplexing solution, to eliminating the problems caused by the air coming from the outside in, or to remove the environmental issues of the production processes by cleaning the outgoing air.

Genano Tube

Genano Tube air purification units combine

Genano product family



Genano Tube air purifier offers a variety of installation options for different environments.

precise air purification and a large air volume. The unit is very easy to install as a device to circulate and clean the indoor air. It can also easily be channeled to achieve a carefully controlled air circulation.

The Genano Tube can also be delivered as a channel installed model where a separate ventilation unit takes care of the air flow. The purification unit is equipped with a separate control unit, which is attached to the device or it can be mounted separately on the wall, for example. The control unit is controlled by a remote control so the cleaner can be safely installed on the wall or ceiling. The Genano Tube can also be located in a different room

than the control unit. Like all Genano air purifiers, the Genano Tube also filters nanoparticles. The Genano Tube is equipped with a collection surface that is replaced from time to time and also, alternatively, a coarse filter or activated charcoal. The latter also removes VOC gases. The air purifier unit weighs only about 15 kgs so it can also be easily relocated or transported with mobile work that is generating air pollution.

Genano 200 and 310 room air purifiers

The Genano product family also includes portable room air purifiers that can effectively improve the air quality of office space if the offices are located near the production site.



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Carbodeon

Carbodeon

Carbodeon manufactures and markets carbon-based nanomaterials. The company's products include:

uDiamond® nano diamonds

uDiamond® nano-diamonds are diamonds that have a diameter of a few nanometers.

Nano-diamonds are used, for example, in the polishing of hard materials, manufacturing high-

strength and lightweight composite materials and coatings, and as lubrication additives.

Nicanite®

Nicanite® is a graphite structured carbon nitride that can be used in coating applications requiring the utmost transparency, and mechanical and chemical durability. The material is resistant to high temperatures and the coefficient of friction is low. Carbodeon produces and develops granular carbon nitride and further sintered targets for coating.



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Avalon® hybrid coatings – a nanotechnology using environmentally friendly method

The unique Avalon® product family provides sustainable and environmentally friendly functional surfaces. Avalon® coating is needed when you want easily cleaned, hygienic, antimicrobial, corrosion-resistant and scratch-proof surfaces for different platforms.

Nanotechnology-based Avalon® coatings exceed the properties of conventional coatings, and

can be used in various types of applications, such as home decoration, surfaces of machines and equipment, and surfaces for industrial environments. In addition, Avalon® coatings provide better visibility and increased safety in automotive, rail and marine applications.

The Avalon® family of hybrid coatings can be used in single- or double-sided applications. The

coating can be easily fabricated onto product on it's final location or as part of the production line. These coatings can be applied by spraying, wiping or dipping. One layer of coating is sufficient to provide complete functionality.

Some products

- Avalon 22 – Easy-to-clean/antimicrobial coating for glass, ceramic surfaces, steel, etc. Transparent/invisible.
- Avalon 25 – Self-cleaning/Easy-to-clean coating for glass and ceramic surfaces. Water and oil (i.e., stain) resistant. Transparent/invisible. Coating can be applied at room temperature.
- Avalon 27 – Self-cleaning/Easy-to-clean coating for stainless steel.
- Avalon 34 – Protective coating for sandblasted glass. Prevents fouling and fingerprints. Softens rough surfaces and gives the impression of a etched glass.

Typical applications

Industrial applications and furniture glass

- Oven glass and stove hoods
- Shower cabinets
- Display screens, counters, refrigerators
- Touch panels, TV screens

Decorating glass

- Shower enclosures, sauna doors
- Glass doors, handrails
- Facade glass

Cars and other

- Windshields and side windows of cars and buses
- Aircraft and train glazing
- Boating glass surfaces and glazing

Stone and tile surfaces

- Sanitary facilities

Steel and non-ferrous metal surfaces

- Stainless steel protection against fingerprints
- Copper and brass corrosion protection and fingerprint protection
- Antimicrobial surfaces for metals



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DIARC-Diamond surface removes losses from machines

Improving the efficiency of machinery and equipment efficiency has an increasingly important role as environmental awareness grows. At the same time, machines still require better performance and reliability. Low friction DIARC-diamond coating can improve both the efficiency and reliability of operation of the main components.

Excellent durability

DIARC-Technology Oy has developed an amorphous diamond coating that is extremely hard and durable. For example, its wear resistance is about a thousand times that of hardened steel. The coating provides good protection even when thin, only a few micrometers in thickness. The coating process takes place at low temperatures and is suitable for use in almost all machinery that use structural materials.

Low friction

In amorphous diamond coating, the friction coefficient against the steel is low - just less than one fifth of the friction coefficient of lubricated steel-steel contact. The coating acts as a dry lubricant and reduces the friction also with the presence lubricants. As a result, for example, friction losses in hydraulics

and transmission devices can be significantly reduced. For example, the efficiency of large hydraulic motors can be improved by almost 30% by coating the components with DIARC-diamond coating. Coated components are used in numerous equipment in process industry due to its good chemical durability, which guarantees the smooth operation of machinery and equipment.

Easy set up

The coating method is suitable for large production runs as well as to small batch and single unit runs. Setup is simple because the coating is so thin that neither the sizing nor the structural materials need to be changed due to the low processing temperature.

Functionality

In addition to the amorphous diamond coating, the DIARC method is suitable for the production of functional nano-coatings and metal-coatings. Nano-coatings are ideal for metals, plastics and ceramics whose properties, such as conductivity, cleanliness, or electrical conductivity are sought to be changed. DIARC is constantly developing new surface solutions together with customers for a wide variety of needs.



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Dyrel-polymeric surfaces – added value from nanotechnology for functional coatings

Using exceptional Dyrel-polymers, easily cleanable, wear resistant and anti-microbial surfaces can be created for a wide variety of industrial applications. Chemically strengthened and modified, Dyrel-coating resins offer many advantages compared to traditional non-stick coatings: easy processing, flexible implementation of hardening and good wear resistance. Other Dyrel coating advantages include high heat tolerance and excellent chemical resistance. They can be used with a variety of coating methods and hardening procedures. Dyrel coatings are typically 20–2000 µm (0.02–2 mm) thick, depending on the product.

Easy to clean and wear-and corrosion resistance properties combined with excellent usability - Millidyne Oy provides solutions to challenging coating problems.

Millidyne is a high technology company that provides advanced solutions for a variety of surface and coating requirements. Our concept is based on the high value-adding standard products that can be flexibly modified based on customer needs and products. We have over 10 years of experience behind us. Millidyne creates unique products based on ceramic composite powders, hybrid coatings and spe-



cialty polymers. We apply nano-technological innovations that make our customer's surfaces even better. Dirt free steel, water-repellent glass, scratch-resistant plastic ... Whatever kind of surface you want for your product. We offer the coating solution.

A few selected properties of resin grades

D3000

- Hardening at room temperature.
- Low friction and high wear resistance.
- Suitable for marine and underwater use.
- Different colors.

D3500

- Hardening at room temperature.
- Medium-sized friction and high wear resistance.
- For applications requiring easy cleanability.



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BALINIT® – surfaces

Oerlikon Balzers is the world leading manufacturer of performance improving surfaces for tooling and precision components. The Finnish production units are located in Pirkkala, in the immediate vicinity of the Tampere-Pirkkala airport.

Coatings manufactured under BALINIT® brand are just a few thousandths of a millimeter thick, very hard, and they significantly reduce the friction and wear.

BALINIT® coatings can reduce or altogether remove the damage due to wear on different tool or components. Through damage prevention, the performance of tools and components can be improved and service intervals extended. This can be used to achieve more effective processes and cost-efficient production.

We offer a wide range of coating and surface processing services for your company's needs:

- PVD coating
- CVD coating
- PPD treatment
- Coatings-related technical assistance

Mechanical pre-and post-processing

Oerlikon Balzers offers coating for the following industries, among others:

- Engineering industry
- Thin sheet metal industry
- Food and pharmaceutical (FDA certified)
- Paper and pulp production
- Sawmill industry
- Hot and cold molding of metals
- Die casting industry
- Plastic and rubber industry

Co-operation with experts in various fields ensures a reliable service regardless of the application target.



oerlikon
balzers

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Picosun's corrosion resistant coatings



Picosun thin films can significantly improve the corrosion resistance of metal surfaces. Using atomic layer deposition (ALD), produced films are pin-hole free and contain very little impurities compared to films produced by other methods. This is because of the exceptional growth process that occurs one atomic layer at a time. ALD can be used in a wide variety of applications and with this method, it is possible to make extremely homogenous coatings even for large pieces.

At present, Picosun is actively involved in leading international research projects aimed at finding innovative solutions to take advantage of high-quality thin films for industrial applications. Picosun currently participates as an active member in, for example, an EU FP7 project 'Corral' which searches for better ways for nano-scale ALD thin films to be used in industrial anti-corrosion applications.

Picosun develops and manufactures ALD process equipment for research and industrial needs. The company has a solid basis from an over thirty-year history in ALD device development in Finland. The inventor of the technique, Dr. Tuomo Suntola, is member of the Picosun Board of Directors. Technical Director Sven Lindfors has designed ALD equipment since 1975. Collectively, Picosun's staff has over 200 years of experience in the application of ALD and have influenced more than 100 ALD patents. Picosun ALD equipment have reached extremely popular status internationally both with research units and in the industrial sector.



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Teknos Oy – Paints and coatings



Teknos is Scandinavia's leading industrial paint manufacturer and it has a strong position in the retail and architectural paint markets. Teknos has its own companies operating in all the Nordic countries and Germany, England, Ireland, Poland, Slovenia, Russia, Ukraine and China. In addition, it has a sales representative network operating in some twenty other European countries.

Teknos' comprehensive product range includes liquid paints and coatings for metal, wood,

mineral and plastic surfaces. Alongside traditional solvent thinner products, Teknos has developed alternative water-based thinner products for all metal objects. The product range is complemented by the low solvent concentration 1-layer paints, which dry quickly, shortening the paint shop lead times and thereby enhancing the effectiveness of paint shops. Extremely high solids content and low VOC emission 2-component paints represent the latest technology.

Teknos' high-quality and cost-effective INFRALIT powder paints are completely solvent-free and an excellent alternative for paint shops emphasizing environmentally friendliness.

Teknos represents strong expertise in the surface treatment of metals and steel and invests heavily in research and product development. Teknos actively follows nanotechnology and has already implemented nano-technological solutions in a part of its products.



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Stratum Oy

Electrolytic nano surfaces for demanding industrial applications

Electrochemical nano-coatings of metals provide superior wear resistance, hardness, sliding properties and corrosion resistance. Stratum nano-surfaces extend service intervals and ensure the operation of the equipment in the paper and wood product industry, in the pumping and controlling of aggressive substances, and in hydraulics solutions. In the pursuit for the greatest reliability in, for example, nuclear reactors or aviation, only electrolytic coatings such as various nano-chrome surfaces can guarantee long-lasting, trouble-free operation.

Surface treatment services

We work together with our customers to find technically and economically optimized solutions for the demanding coatings of

various metals. Stratum's in-house developed 3D modeling software enable the highest quality, and support our customers' product development and competitiveness in the early design stages of a product. Our three separate self-designed and manufactureed surface finishing facilities are capable of handling customer products from the smallest valve parts to large plywood press surfaces and the head boxes of full-width, high-speed paper machines.

Engineering services

We also design and deliver surface treatment equipment and processes to be used in our customers' own manufacturing units. Our expertise in the environmental requirements and controls of the plants provide sustainable solutions to even most challenging processes.

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Epilogue

Nanotechnology and new materials technology are strong research and product development targets, and new applications and solutions arise all the time. Nanomaterials have attracted great interest because they make it possible to create materials with unprecedented properties. Basic research plays an important role in the development of nanotechnology and through it brand-new features can be found from materials. Hence, entirely new solutions develop. This development can nevertheless be very time consuming, so technical applications that control atoms at the molecular level are usually expected only after many years after they have been shown to be effective in the laboratory. Consequently, many new applica-

tions containing nanotechnology and new materials are essentially improved versions of previously known applications. Entirely new, unprecedented applications made possible by nanotechnology have so far been limited, but their number is expected to grow.

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Leverage from
the EU
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ympäristökeskus