NanoMarkets Report

Worldwide Smart Coatings Markets

2013 – 2020

Nano-657

Published November 2013

www.nanomarkets.net

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SUMMARY

Smart coatings change in response to external stimuli and are finding a fast growing number of applications in several industries including construction, automotive, medical, consumer electronic goods and the military. NanoMarkets believes that these materials present a strong business case because of their unique functionality and their ability to be highly customized. We think smart coatings will do especially well in medical, military and other applications, where quality and performance, rather than price, shape purchasing decisions. Consumer markets where the customer is willing to pay a premium for functionality such as scratch resistance or enhanced energy efficiency will also be important.

NanoMarkets commenced coverage of smart coatings in 2011. As such, it has a solid understanding of the dynamics of the smart coatings business and it brings this experience to this report. The report covers all the major markets for smart coatings including energy, automotive, medical, electronics, textiles and military. And it includes an assessment of the product/marketing strategies of key firms supplying smart coatings, as well as eight-year forecasts by applications sector and by type of coating. These forecasts are both in volume and in value terms.

This report also assesses the latest technical developments in the smart coatings space; smart coatings are becoming smarter and more biological, for example Based on the latest R&D and university research, we also examines future directions for smart coatings including important developments in manufacturing. We believe that this report will provide guidance to coatings and other specialty chemical firms, as well as firms making production equipment, and others planning to make investments of all kinds in smart materials.

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Chapter One: Introduction

1.1 Background to the Report

1.1.1 Brief about Smart Coatings

Smart coatings are typically defined as a film composed of unique materials with pre-defined properties that can change in response to an external stimulus, such as light, electric current, pressure, etc. Ideally, a smart coating can be tailor-made to suit the needs of the consumer and can thus act in very different ways for different applications.

There are no set criteria for smart coatings, and it is the end-use of the coating application that defines the material choice and inherent characteristics of a smart coating. In this report, therefore, we have also included coatings that are specifically intended to stand up to extreme conditions and respond by not responding, which is the characteristic that makes them smart. While there is an obvious paradox here, this type of coating has many of the same types of commercial and technical characteristics as the responsive type of smart coating.

The term 'Smart Coating' broadly refers to a gamut of coating materials with varied chemical, physical, mechanical, and electrical properties that find applications in a wide range of industries, from the construction to the textile sectors. However, in terms of business attractiveness and revenue generation, the scope of smart coatings is limited to a handful of key industrial and commercial segments, including the construction, automotive, medical, consumer electronic goods, and military sectors.

Because of their ability to offer customized benefits to suit the requirements of the end user, smart coatings are likely to demand a premium price in comparison to conventional coatings. Hence, it is important to ascertain the cost-benefit proposition so that the attractiveness of a particular type of smart coating for a target consumer segment can be gauged.

Some application areas, such as military and medical, are likely to adopt unique smart coatings with unmatched benefits despite their high prices, because these segments are typically more sensitive to quality than price. At the same time, some relatively new consumer segments, such as high-end consumer electronics, may adopt smart coatings because of their favorable scratch-resistance or visual enhancement features. Others, such as commercial building owners, are likely to be more interested in the temperature and privacy control features of smart coatings.

1.1.2 Improving Scope for Medical Applications

Smart coatings can be customized to create a toxic or non-toxic barrier for harmful microorganisms. As a result, smart coatings are increasingly used in medical applications as antimicrobial agents. In addition, the triggering mechanism in smart coatings to activate a specific functionality can be harnessed to develop efficient drug-delivery systems; however, such systems are not likely to be commercialized in the immediate future.

Antimicrobial coatings: The applicability of smart coatings as antimicrobial agents has extended beyond medical uses to the food, textile, and residential segments, in which protection from bacterial and fungal growth has gained significant importance in recent years.

Some of the established material specialists in this space offer antimicrobial coatings based on patented non-toxic silver technology for application in hygiene-sensitive areas such as hospitals and food processing facilities. DuPont (U.S.), for example, has licensed industrial applicators (for instance, Plas-Tech Coatings (U.S.) that apply its antimicrobial Teflon industrial coatings in the healthcare, food processing, and pharmaceutical industries.

These coatings typically rely on the sustained release of silver ions (from a silver-based antimicrobial compound dispersed in an inert matrix), ensuring extended antimicrobial functionality throughout the lifetime of the coating.

- Another innovative firm actively working in the antimicrobial coating space has been Reactive Surfaces Ltd. (U.S.), which offers enzyme and peptide-based additives for antimicrobial coatings. Some of the key applications of such useful additives in the antimicrobial coating system include the development of biocidal surfaces, mold-inhibiting surfaces, and catalytic column coatings for liquid and gaseous waste-stream decontamination.

- Other firms have developed antimicrobial coatings that work via physical mechanisms, leading to the destruction of the thin cell walls of microbes. Such technology depends on the ability of stabilized silane molecules (microbe defenders) to remain suspended in water, forming a long-lasting antimicrobial barrier on top of the underlying surface. Some of the commercial smart coating solutions in this domain can be safely applied on a range of medical surfaces, including intravenous stands, instrument trays, beds, X-ray tables, lab coats, towels and patient gowns, among others.

Typically, antimicrobial coating manufacturers claim to offer long-term protection against a range of microorganisms, thus reducing the disinfecting and cleaning cycles in health-conscious environments. There are, in fact, several players in the market that specialize in providing non-leaching and water-based antimicrobial coatings that can be applied on a host of surfaces and fabrics.

Innovative drug delivery agents: The majority of smart coatings that are meant to trigger automatic drug release based on an external stimuli (an electric current, for instance) are currently in the research phase and there is uncertainty over the commercial release of such advanced drug delivery systems in the immediate future.

Switzerland-based Debiotech SA is among the few companies that are experimenting with nanoporous membrane-based refillable and single-use drug delivery systems (DDS) that are yet to be commercialized. Others are in the process of attempting to utilize nanoparticle technology to treat brain disorders, such as Alzheimer's disease, via the transport of pharmaceutically active compounds embedded in nanoparticles across the blood-brain barrier.

Several research initiatives are also underway in this space. A prominent program involves the development of bioadhesive coatings by researchers at the UCLA Henry Samueli School of Engineering and Applied Science (U.S.). When such coatings are applied to nanoparticles capable of carrying active biopharmaceutical compounds, the nanoparticles are able to stick to the mucosal lining of the intestines, thereby allowing efficient absorption into the bloodstream.

Another potential application of bioadhesive coatings is controlled drug release for the prevention of drug overdoses in critical situations. Such systems usually rely on stimuli-responsive materials that trigger drug release only when they are in the 'on' state.

However, before commercialization of such advanced technologies is possible, much additional development work is required, and they must also be subjected to clinical trial evaluations. As a result, NanoMarkets believes that, despite an established market for conventional DDS, commercialization of smart-drug delivery systems based on smart coatings will not occur during the period covered by this report.

However, due to the increased incidence of microbial infections in healthcare and other related fields, NanoMarkets believes that consumers will embrace antimicrobial smart coatings more readily than others, because hygiene and quality are of utmost importance for these consumer segments.

As a result, NanoMarkets believes that smart coating manufacturers will be more profitable if they develop innovative products specifically designed for the medical and allied segments. NanoMarkets also expects that antimicrobial thin-film coatings will be the most desirable products in this segment in the coming years, followed by smart coating-based DDS.

1.1.3 Growing Scope for Military Applications

The military sector, particularly the U.S. military, has shown continued interest in the adoption of new materials to meet its requirements for anti-corrosive solutions to reduce repair and maintenance work for various equipment and intelligent camouflaging techniques to mask equipment and personnel.

Innovative firms have responded with the development of increasingly effective and environmentally friendly coating solutions. For instance, AnCatt Inc. (U.S.) is preparing for the commercial production of its proprietary polyaniline-based anti-corrosion coating for use on military aircraft. NanoMarkets believes that the development of novel coatings that protect galvanized steel and aluminum surfaces will increase the potential application range of innovative smart coatings.

The U.S. military is also working with some innovative coating manufacturers, such as Tesla NanoCoatings (U.S.), to develop unique anti-corrosion coatings based on carbon nanotube/zinc-hybrid compounds, some of which have been demonstrated to match the corrosion protection levels achieved by more conventional metallic zinc-rich primer systems.

At the same time, the ease of installation of such anti-corrosion coatings compared to conventional metallic-zinc primer systems will enable the U.S. military to adopt a cost-effective approach for the restoration of the outer metallic surfaces of military structures, such as fuel tanks.

NanoMarkets believes that the ability of such smart coatings to extend the service life, reduce operational costs, and improve the chemical resistance of steel structures relevant to military applications will lead to the adoption of these materials for other related military applications in the medium term.

Good potential in new application areas: Although military applications are already served by smart coatings, innovative smart coatings, such as those capable of generating energy, have also attracted the attention of the U.S. military and the scientific community. For example, the scope of

certain patent-pending transparent, electricity-generating coatings has been expanded in 2013 to meet the requirements of commercial and military aircraft. There is potential for use of such coatings on aircraft windows, fuselage surfaces, and related components, as well as pilot flight suits, helmets, and visors.

NanoMarkets believes that such new developments are likely to gain prominence in the coming years, because energy-generating smart coatings have the potential to act as an emergency electricity source that could enhance passenger and pilot safety in times of distress.

Overall, NanoMarkets believes that more traditional applications of smart coatings, such as camouflaging and anti-corrosion protection, will continue to dominate the military segment in the near to medium term, while energy-generating coatings will gain widespread acceptance in the medium to long term.

1.1.4 Energy Applications to Receive a Boost

As energy producers continue to work in unconventional environments, such as at great depths, pressures, and temperatures, and as refinery workers, manufacturing plant owners, and pipeline operators continue to seek new ways to improve operational efficiency and reduce the threat of corrosion, there is great need for advanced materials such as smart coatings.

Customized surface engineering-related coatings: These coatings are specifically meant to tackle extreme chemical, physical, and mechanical environments. U.K.-based Monitor Coatings (MC), now part of Switzerland-based Castolin Eutectic, is one company that has a wide range of smart coatings designed for use in severe operating environments, and offers ultra-dense, highly wear-resistant coatings to the oil and gas industry through patented thermal spray and densification processes.

The coatings, typically comprised of sealants and applied via a high-velocity oxy-fuel (HVOF) spray technique, are meant to offer superior protection against corrosion and frictional wear and tear compared to conventional coatings. In general, coatings for this segment primarily offer wear resistance, thermal insulation, and electrical insulation and help retain the original magnetic, electronic, and dimensional properties of the substrate. MC uses a different combination of raw materials for the development of smart coatings to suit particular requirements.

While carbide-coated and ceramic-sealed mud motor rotors have been shown to operate efficiently in chloride concentrations exceeding 350,000 ppm (parts per million), tungsten-based high-velocity thermal spray coatings have been developed to make rock drill bit components more resistant to wear and impact.

NanoMarkets believes that the energy industry will rely heavily on advanced smart coatings with extended wear and tear resistance that cannot be achieved with the use of conventional coatings, to reach optimal levels of operational efficiency.

Hard coatings: These very specialized coatings are typically used on valves deployed in the oil and gas industry. Hardide Coatings Ltd. (U.K.) is one company that offers such coatings commercially under the brand name Hardide. The nanostructured coating of tungsten-carbide particles can be conveniently applied using a low-temperature chemical vapor deposition process to achieve a nearly pore-free film.

The uniqueness of the uniform pore-free film, which is difficult to achieve with conventional coating systems, is of prime importance for the safe operation of gas valves, preventing gas leakage and subsequent threats of explosion.

NanoMarkets believes that there is great potential in the energy space for such highly specialized smart coatings that can be applied on directional drilling tools with mud-driven hydraulic parts, thus extending the drilling time and reducing part replacement frequency.

NanoMarkets believes that the recent collaboration between British Petroleum and the University of Manchester (U.K.) to develop energy-efficient materials, including smart coatings, will be considered a significant move by smart coating manufacturers seeking to serve the energy segment. NanoMarkets further believes that the energy segment will be best served by specialized coating manufacturers that can tap into more opportunities spanning across the downstream and upstream segments of the oil and gas industry in the near to medium term.

1.1.5 Demand from the Transportation Sector Likely to Revive

Despite the slow recovery of the European automotive market, the global automotive industry will experience moderate growth due to increasing demand in North America and the Asia-Pacific region (particularly from China). As a result, smart coating manufacturers targeting automobile applications will witness a moderate growth phase in the coming years. There are, in fact, several existing smart coatings with established applications or strong potential in the automotive sector.

Self-stratifying coatings: Traditionally, a clear coat is used over a pigmented base paint to provide satisfactory external durability. However, the labor and material costs involved in the application of a second coating on automobiles has been an issue in the industry for some time. As a result, self-stratifying coatings that are able to form multilayer films from a single coating system have started to gain prominence in the automobile industry, which is looking to cut operating expenses.

This segment has drawn the interest of a few globally reputed paint and materials firms, such as Netherlands-based AkzoNobel. In addition, the North American counterpart of Toyota (Japan) recently received a joint patent with Eastern Michigan University (U.S.) for three unique self-stratifying coatings that have the potential to streamline the overall coating process and reduce manufacturing costs.

NanoMarkets believes that a one-step coating process that leads to the separation of two different functional layers can offer a sustainable and economical next-generation automobile painting process. Given the potential of self-stratifying coatings to offer multiple advantages, such as enhanced mechanical strength, wear resistance, and adhesion performance with minimal operational hassles and reasonable costs, NanoMarkets believes that such coatings will garner higher demand in the near to mid-term.

Self-healing coatings: These coatings are mostly designed to offer scratch resistance benefits, but some have been demonstrated to exhibit self-repairing capabilities when exposed to heat and sunlight. There are, in fact, commercial self-cleaning coating systems from reputed firms that incorporate a dedicated hardener and softener.

In addition, companies are actively pursuing the development of self-healing clearcoats that can repair scratches upon activation by heat. *NanoMarkets believes that the emergence of the*

participation of reputable coating manufacturers in this domain will expand the possible application range of energy-saving smart coatings in the automobile segment.

Energy-saving smart coatings: One of the potential benefits of smart coatings for automobile applications is to reduce energy consumption, which not only reduces fuel consumption and carbon-dioxide emissions, but also creates a comfortable interior environment for the passengers.

Anti-reflective and selective absorption are some of the key coating properties that can be utilized in the energy-saving applications. Research Frontiers, Inc. (RFI) is probably the only company that holds multiple patents in the active electrochromic smart coatings space. RFI typically licenses its technology to multiple original equipment manufacturers (OEMs) belonging to the automobile, aerospace, and marine industries.

By applying an electric current through a variety of underlying substrates (including glass, polycarbonate, and acrylic) embedded with suspended particles, RFI is able to quickly switch the surface from transparent to opaque.

NanoMarkets believes that the growing interest of leading players in the automotive and aerospace industries in potential energy-savings will generate reasonable demand for smart coatings in this space.

Customized aerospace coatings: Growing concerns over passenger safety and the wear and tear of critical aircraft components have attracted the industry's attention to smart coatings. Companies that offer smart coatings to the aerospace and defense industries have benefited as a result.

The demand for certain types of industry-specific smart coatings for aircraft bodies and critical aircraft components has been elevated by the requirement for high levels of protection, particularly against corrosion, under extreme environmental conditions. To date, conventional coating systems have failed to meet such expectations for the airline industry.

As a result, an important material strategy in this space has arisen that involves the use of organic coating materials, such as epoxies, silicones, polyurethanes, and polyimides, as well as resin blends and metallic-ceramic blends, in smart coatings capable of demonstrating high resistance to corrosion, chemicals, and UV radiation at elevated temperatures.

NanoMarkets believes that the active involvement of several reputable aerospace players in this space will elevate the prospects for advanced smart coatings that can meet the customized and high-quality requirements of the aerospace industry.

Although the majority of currently available smart coatings for automobile applications has been limited to a few important functionalities, such as enhancing durability and ensuring color uniformity, NanoMarkets believes that advances in material science have enabled the development of smart coatings with a wider array of capabilities, such as self-healing and energy-efficiency properties. As a result, we expect that companies focusing their research efforts on these emerging aspects will benefit in the long run.

1.1.6 Electronic Industry Represents a New and Potential Application Area

The electronics industry, including touch-screen displays, is one of the largest potential consumers of smart coatings. Smart coatings developed for such applications can be formulated to offer multiple functionalities, with screen protection and intelligent response to external stimuli garnering the greatest attention recently. In addition, there are two key factors that can substantially boost the adoption rate of smart coatings by the electronic industry.

Entry of reputed raw material suppliers: Bayer MaterialScience (Germany) is an established materials science company that has shown an active interest in developing smart coatings for electronic applications, as evident from its involvement in 2012 in the development of 'temporary functional coatings' based on Bayhydrol, one of the company's proprietary polyurethane dispersions.

Bayhydrol can be conveniently incorporated into the mass production lines in the electronics industry, ensuring that sensitive displays are protected from damage during the milling process. These temporary coatings, which can be peeled off once they serve their purpose, are meant to protect touch screens against damage from dust and other chemical and mechanical agents.

Self-healing coatings can also be explored by coating manufacturers. For instance, specially formulated waterborne polyurethane dispersions have been shown to conveniently realign themselves to fill in scratches, primarily due to the elastically reversible hydrogen bonds formed between the polymer chains in the coating binder.

Favorable investment climate: NanoMarkets expects that ongoing research efforts in this area will result in the launch of commercial solutions in the coming years. Innovative coatings, such as those with a super-amphiphobic nature (demonstrating both hydrophobic and hydrophilic characteristics) are being developed that may be capable of repelling water and dirt-based deposits from a variety of surfaces, including glass, metal, wood, ceramic, textiles, and paper.

NanoMarkets believes that the potential applications of such smart coatings across different industries will attract investment, particularly in the consumer electronics segment, where constant innovation is a prerequisite to continued success .

NanoMarkets also believes that protective smart coatings will be of prime importance to smartphone users in the near to immediate future as high-end electronic display device users seek to protect their devices from hydrolytic, yellowing, and chemical effects. Furthermore, we expect that the presence of established smart coating manufacturers in this market will brighten up the prospects for others because global growth in demand for high-end consumer electronic display devices will remain steady in the coming years.

1.1.7 Construction Applications Continue to be Affected by Premium Pricing and Current Economic Conditions

In this segment, smart coatings are mostly applied to window surfaces. Demand largely originated from the new residential and commercial construction segments, rather than from retrofitting arrangements, because the latter Isa more costly venture. Smart window coatings are primarily based on two different technologies.

Electrochromic coatings: By virtue of this technology, windows can be made to deliver specific benefits, such as privacy or heat insulation via the application of a low amount of electric current. Although the end user is able to receive on-demand benefits at the flip of a mechanical switch, the continuous requirement of electric energy can impact overall energy costs. On the other hand, cost savings resulting from the elimination of air-conditioning and window curtains can justify the premium cost of windows containing smart coatings.

It should also be noted that there are several companies offering active electrochromic glass with embedded smart coating technology. Of particular interest are products based on SPD (Suspended Particle Device) technology, which are suited for construction and automotive applications. There are also other potential technologies of interest in this space, such as electricity–generating glass that can deliver multiple benefits.

In recent years, several U.S. start-ups have been successful at raising funding for the development of electrochromic window coating solutions for high-end residential and commercial buildings. With the startup of large-scale electrochromic window coating production facilities, NanoMarkets believes that sizable Asian and North American markets will develop in the medium term. In addition, the cost of electrochromic coatings is expected to decline in the coming years, making these products more appealing to a wider audience.

However, NanoMarkets believes that it will be several more years before electrochromic coatings reach a reasonable price point at which consumers will be willing to adopt such smart coating embedded solutions on a regular basis. In addition, the future potential of electrochromic window coatings will largely hinge on the overall economic situation prevalent in the construction industry.

Photochromic coatings: Coatings based on this type of technology ideally rely on natural stimuli (heat, light, etc.) to perform a specific function, such as providing privacy or protection from ultraviolet rays by changing from transparent to opaque. Although these types of coatings are relatively less costly and cumbersome to own than electrochromic systems, the end user does not have the option to receive instant benefits. Nearly all of the major glass manufacturers have some form of photochromic coating for glass designed for use in construction applications.

NanoMarkets believes that the prospects for photochromic coatings will be better than that for electrochromic coatings. However, the level of market penetration will primarily depend on the ability of new building developers to adopt such high-quality building materials with a premium price tag.

Potential of energy-generating smart coatings and intelligent walls: *Although these types of smart coatings are relatively new, NanoMarkets believes that a market for such coatings can materialize in the long run as building owners seek newer ways to reduce energy consumption.*

For instance, patents have already been granted for see-through energy-generating smart coating solutions in the U.S., opening up the possibility for commercial production in the near to medium term.

In addition, technology has been developed that enables the spraying of very small, functional organic solar cells on the top of transparent glass at room temperature (unlike the high temperatures required for high-vacuum production techniques). The cells can generate electricity not only from natural sunlight, but also from artificial light sources such as compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs).

The ability to fabricate such coatings with reliable electrical and optical absorption properties from environmentally friendly hydrocarbons and apply them on a range of substrates (glass, plastic, and paper) using a variety of wet chemistry techniques, such as screen printing, inkjet printing, and spraying are critical factors that can enhance the scope of commercial adoption of such films in the longer run.

However, NanoMarkets believes that consumer acceptance will depend largely on the pricing and perceived cost-benefit proposition of such value-added coating materials.

Other patented coating solutions for the residential segment include waterborne coatings capable of reducing heat transfer and providing insulation. Typically, these coatings can be applied over pre-painted surfaces just like a regular water-based paint.

One such patented product currently sold in the United States has been developed by Industrial Nanotech Inc. (U.S.), which offers 'Nansulate' smart coatings. The ability to obtain points towards LEED (Leadership in Energy and Environmental Design) certification by using these coatings for both new and pre-existing buildings give the company an advantage in the marketplace.

Despite the high potential of smart coatings to offer unique benefits for residential and commercial building owners, their market penetration has been low, primarily due to the premium pricing structure.

NanoMarkets believes that expansion of the market for smart coatings in the construction segment will primarily depend on the health of the new construction market. In addition, the current pricing structure must be rationalized in the coming years to one that will provide builders a reasonable payback period for their investments in windows with smart coating technology.

In addition, the greatest potential for construction-specific smart coatings will be in emerging economies such as China, where the government push towards energy-efficient buildings will drive near-term demand for highly functional windows containing smart coatings.

1.2 Objectives and Scope of this Report

NanoMarkets has been providing industry analysis of the smart coatings market for over three years and is a leading supplier of analysis in this space. This report is the latest NanoMarkets report on opportunities in the smart coatings market with respect to material choices and applications. The goal of this report is to analyze and forecast the prospects for smart coating applications and materials choices in the coming eight years.

This report identifies and quantifies the opportunities, challenges, and prospects for growth in the smart windows market. Specifically, it covers smart coating technologies, emerging markets and applications, supply chain dynamics and leading firms, and other growth drivers, and presents our eight-year forecasts for the smart coatings market.

Because smart coatings are used in such a wide variety of applications, the scope of the report has been limited to applications with the greatest market potential over the forecasting period considered here. In addition, the report is written with a focus on existing and emerging technologies that are close to commercialization. Less space and effort is devoted to coatings that exist only on laboratory benches. However, exceptions are made when the opportunity is exceptionally large.

NanoMarkets believes that smart coatings will continue to proliferate as prices come down and functionality improves. The key growth drivers are the lower cost of ownership in price-sensitive markets and novel functionality in price-insensitive segments. There are opportunities for growth in all market segments reviewed in the report—medical, military, energy, transportation, electronics, and construction.

By reviewing emerging technologies across a variety of applications, we show where new business revenues can be created and existing smart coatings can find new markets in the next eight years, and present our forecasts by application and material or functionality.

1.3 Methodology of this Report

This report is based on NanoMarkets' ongoing industry research in the area of smart coatings and related materials. Keeping pace with the dynamically changing technological environment, NanoMarkets has not only considered the mainstream applications of diverse types of smart coatings, but also investigated niche and upcoming application areas that have promising growth potential for smart coatings.

The information in this report comes from a variety of sources, but principally comes from primary interviews with insiders in the field of smart coatings commercialization, including entrepreneurs, business owners, business development and marketing managers, and technologists.

Secondary research was based on a variety of sources, such as information available on the World Wide Web, technical journals, press releases, trade press articles, government databases, company literature, and SEC filings and used to further elucidate major trends in the smart coatings market.

The forecasting approach taken and the assumptions made when preparing the forecasts in this report are explained in more detail in Chapter Three, but the basic approach taken here was to identify and quantify the underlying addressable markets, the penetration of various smart coating technologies in those markets, and how other market elements may impact the growth in demand for smart coatings.

In addition, some of the data for this report comes from the previous NanoMarkets report *"Smart Coatings Markets – 2011"* (February 2011). Whenever information has been used from an earlier report, we have reinvestigated, reanalyzed, and reconsidered it in light of the current market status.

This report is entirely international in scope. The forecasts are worldwide forecasts and we have not been geographically selective in the firms that we have covered in the report or interviewed in order to collect information. However, a certain degree of emphasis has been placed on the developed world, because most of the research around smart coatings is pursued in the developed world. The firms and research discussed in this report were selected by importance, not by location.

1.4 Plan of this Report

Chapter Two presents an overview of the emerging materials and research trends across the various smart coating applications highlighted in this report. It covers both work done in the private sector at large and small companies and military research. Where applicable to commercialization, university research is also discussed. A special focus is placed on the value proposition of the coatings.

Chapter Three broadly discusses the state of the smart-coatings end-use markets and where they are heading. This chapter is segmented by application, and the emphasis is on the largest opportunities, which are not necessarily the largest markets. Simultaneously, this chapter also provides our eight-year forecasts for the smart coating technologies and applications that are discussed in the report.