FUNCTIONAL COATINGS 2:
Megatrends and Market Needs

By Cynthia Challener,
CoatingsTech Contributing Writer

Part 1 of this two-part article [CoatingsTech, 12 (2) 22-24, February 2015] explored the industry’s perceptions of functional coatings. In the following, we examine the megatrends that are driving the progress of these coatings, and learn about some of the specific functionalities that are being developed.

Both overarching societal trends and the desire to fulfill unmet market needs on a practical level are driving the development and demand for functional coatings. “The larger trends driving interest in functional coatings are related to enhancing personal well-being and reducing environmental impact. If a coating can reduce maintenance, energy consumption, or enhance daily life through the creation of a healthy environment, it adds value. Given the ubiquitous nature of coatings, particularly their impact on the urban environment, there is a significant benefit to be achieved by the user,” says William Weaver, vice president of R&D and strategy for Nuplex.

To Anne Shim, technical and quality director for BASF coatings in North America, many of the unmet needs appear related to megatrends associated with the needs of humanity. “We are seeing a significant population growth, while at the same time the average age is increasing in some areas and decreasing in others. Water is or will become a scarcity in many parts of the world. Access to food and fuel will become increasingly important too. Functional coatings promise the potential of being a part of the solution to these mega-issues,” she asserts. Some examples include antimicrobial surfaces to improve the health of an aging population; agricultural coatings that improve yields; antifouling coatings that reduce drag resistance and improve fuel consumption for ships; novel coatings that enable lightweighting and improved fuel economy for vehicles; and superhydrophobic, fingerprint-resistant, self-cleaning coatings that reduce water usage for cleaning.

Other macro trends driving demand for functional coatings include the growing interest in improving energy efficiency and indoor air quality, according to Insogna. In addition, Celanese’s Rajeev Farwaha, technical manager, emulsions, Americas,
believes that there is a strong desire to reduce complexity, and functional coatings that reduce the need for maintenance, cleaning, or other activities are benefiting from this trend.

The formulation of coatings with new functionalities (or capabilities transferred from other existing applications) also presents the opportunity to grow volume by expanding into new market segments, according to Insogna. Adding novel functionality also helps coating manufacturers differentiate their products, and often because functional coatings are perceived as higher-value products, they can carry a premium price. “End users don’t care whether a product is photocatalytic or self-healing. What they do care about is having a better user experience, with the reduction or elimination of cleaning, repair, replacement, and/or disposal requirements, and functional coatings are technologies that help deliver these features,” states Wubbels.

Of course, advances in technology are making the development of many of the newest functional coating types possible. For example, developments in nanotechnology are enabling more distinct uses of chemistries previously known only on the macro scale, according to Nathan Kofira, market development manager with ICL\Advanced Additives. As an example, he points to the use of nanosilica particles to impart antireflective properties to functional coatings. ICL has been developing nanomaterials as corrosion inhibitors for coatings with extended service life responsiveness in a variety of corrosive environments.

New resin technologies are equally important and enabling the preparation of binders with novel properties.

**NEWER FUNCTIONALITIES WITH LONGER DEVELOPMENT TIMELINES**

Lux Research, a market research firm that provides strategic advice and ongoing intelligence for emerging technologies, has identified four coating functionalities—hydrophobic, antimicrobial, photocatalytic, and self-healing—as having disruptive potential in the near term, according to its report **Beyond Protection: Scouting for Hot Spots in the Emerging Functional Coatings Market**. “These new functionalities in coatings are the direct result of advances in materials science and nanotechnology and go beyond the original basic protective and decorative attributes generally associated with coatings,” notes Lux Research senior analyst Aditya Ranade. They have the potential to offer numerous benefits, such as antimicrobial protection in the medical industry, self-healing capabilities for infrastructure (e.g., oil and gas pipeline) applications, hydrophobic properties for smudge-free electronics, and photocatalytic decontamination in building construction. While the self-healing and superhydrophobic coatings markets are in the pre-revenue stage, Lux Research estimates the value of the photocatalytic coatings market at approximately $100 million and the hygienic (antimicrobial) coatings market at about $200 million. Farwaha adds that such functional coatings are targeted largely at niche segments, such as the high-value end of the price-performance continuum, where end users are willing to pay extra for the added functions.

**Self-healing Coatings**

Self-healing coatings have significant potential, according to Weaver, but substantial development is still required before they will have a real impact on the broader coating market. “The long-term durability and ability to maintain functionality at an acceptable cost must be achieved first, and based on early results using organic systems, it appears that in some advanced environments such as those experienced in oilfield exploration, where scratch and temperature resistance demands are extreme, it is likely that inorganic/organic hybrids or ceramics will be required,” he adds.

Ranade believes, however, that self-healing coating technology is the most disruptive, but underappreciated. Currently available products include automotive clearcoats that can self-repair minor scratches. Products for more demanding applications, such as in the oil and gas sector, are not yet on the market. Autonomic Materials, founded by Scott White, a professor of aerospace engineering at the University of Illinois’ Beckman Institute and leader of the Autonomous Materials Systems (AMS) group, is a company to watch. It holds the exclusive license to an extensive suite of intellectual property generated by the AMS group, and its products are based on encapsulation technology. Microcapsules incorporated into the coating contain resins and/or monomers and curing agents or catalysts that are released when damage...
occurs. These materials then react and fill in the crack. Because the capsules are visible in these coatings, they are not suitable for automotive applications, but would be appropriate for oil and gas pipelines. Other companies that have been actively filing patents on self-healing coatings include Saint Gobain, Asahi Glass, Siemens, Safran, and Matsushita Electric.

Self-cleaning Coatings

Superhydrophobic coatings (water contact angle of ~150°) are attractive because they exhibit self-cleaning properties. They shed dirt and thus reduce the maintenance required to keep coated surfaces clean. These coatings can be generated through the use of a combination of hydrophobic additives and specially generated surface textures or by using a hydrophobically modified binder in conjunction with special low surface energy silicone or fluorine-based additives, according to Farwaha. Advances in the creation and control of submicron and nanoscale structures and nano-composite technologies have made increasingly superhydrophobic coatings possible.

Weaver believes that self-cleaning functional coatings present the greatest opportunities, given their breadth of potential applications in industries ranging from automotive to interior residential to large-scale exterior architectural. There is also interest in the use of superhydrophobic coatings in the consumer electronics industry for antifingerprint and smudge-free surfaces, as well as water-proofing protection. Ranade points to Nanogate Technologies and Diamon-Fusion International as two companies that appear to be on track for achieving commercial success with hydrophobic coating technologies. Other companies that Lux believes have good potential include Topchim, Lotus Leaf Coatings, ISDurTec, and Oxford Advanced Surfaces. As a raw material supplier, Celanese has developed a nano organic-silica composite acrylic emulsion for the formulation of dirt pickup-resistant high performance coatings.

Additional work is needed on superhydrophobic coatings before they will be widely adopted, however. Durability is the main hurdle, according to Burgess. “Niche applications may be possible today, but the fundamental problems related to resistance to mechanical damage and loss of superhydrophobicity due to surfactant contamination are significant issues with this technology,” he says. On the other hand, anti-icing coatings, which are generally seen as a subset of self-cleaning coatings based on superhydrophobic surfaces, are being developed for the aerospace industry and the prevention of ice buildup on power lines, on the blades of wind turbines, and in various refrigeration applications, according to Kevin Lassila, director of technology for BYK USA. The key will be to identify technologies that can perform for a reasonable number of years.

Photocatalytic Coatings

Photocatalytic coatings are largely composed of nanoparticles of ceramic oxides, with most based on titanium dioxide (TiO₂), but some containing mixtures of TiO₂ with silicon dioxide (SiO₂) and/or zinc oxide (ZnO). Crapper points out that it is unlikely that any photocatalytic coatings will be formulated with organic binders, because organic polymers are degraded during the photocatalytic process, which shortens the practical lifetimes of such coatings.

These coatings have been applied to glass for several years now (e.g., PPG Industries’ SUNCLEAN self-cleaning glass for automotive and architectural applications). Similar to superhydrophobic coatings, photocatalytic coatings are of interest because they can impart anti-dirt pickup, self-cleaning, and/or easy-to-clean properties, according to Lassila. In fact, photocatalytic coatings are also being marketed for use on all types of architectural surfaces, and even as roof coatings, as a way to reduce pollution through the degradation of sulfur and nitrogen oxides (SOx and NOx, respectively). Farwaha notes that they are being promoted for the elimination of VOCs and odors in public spaces. The greatest potential for this type of application, according to Lux Research, is in emerging markets, particularly in many cities in China where air pollution is severe.

Overall, Ranade expects that photocatalytic coatings will have the greatest potential in the
energy and construction sectors. Companies with the greatest number of patents include Toto, Saint Gobain, Showa Denko, Sumitomo Chemical, and PPG Industries. Other companies offering photocatalytic coatings include Evonik, PURETi, Advanced Materials, Green Millennium, and Eco-Active Surfaces.

Antimicrobial Coatings

There is significant interest in the market for antimicrobial, or hygienic, coatings, particularly in the institutional segment—hospitals, schools, prisons, processing facilities, animal housing, and children’s centers—which all have a significant interest in reducing the spread of disease. However, it is also a challenging space, according to David Tierney, global business director for building products with Lonza Industrial Solutions. “It is necessary to conduct extensive testing in order to develop data to support any claims, which requires a measurable investment,” he says. Further complicating the issue is the fact that the data and certification requirements are different on a regional basis, and regulations for hygienic coatings in North America and Europe are poorly developed. Consequently, it is necessary to work very closely with the individual regulatory agencies to ensure that all requirements are met.

Silver has been most widely used as the antimicrobial agent in hygienic coatings, with nanosilver of particular interest recently. However, Tierney notes that with larger silver particles, there can be issues with coatings turning gray, and if the particles agglomerate, they often become deactivated. In addition, there are concerns over the safety of nanosilver, and therefore uncertainties about future regulations are affecting its use. As a result, companies are looking for nonsilver alternatives. Lonza offers pyrithione-based additives for hygienic coatings that reliably achieve the required level of antibacterial protection. Smaller companies, including Alistagen and Reactive Surfaces, offer very different technologies. Alistagen’s Caliwel paint contains sodium hydroxide that is microencapsulated using a proprietary BNA (Bi-Neutralizing) technology, while ProteCoat from Reactive Surfaces is a bioengineered peptide and enzyme-based additive. Other options include encapsulated iodopropynyl butyl carbamate (IPBC) for controlled release, silanes, and quaternary ammonium (quat) compounds, according to Farwaha. Lonza is also investigating possible natural ingredients, such as tea tree oil, as well as various formulation and delivery technologies.

An important point to remember about hygienic coatings, according to Tierney, is that they do not replace proper hygiene practices. “Most major coating manufacturers have expressed an interest in hygienic coatings. However, very few have introduced any products to the market,” he says. The potential liability issues seem to be as real an issue as the regulatory hurdles that must be overcome.

Even so, Ranade of Lux Research believes that antimicrobial or hygienic coatings can be viewed as a highly disruptive technology, particularly in the medical sector. In addition to the smaller companies mentioned above that have already developed commercial products, larger firms have been busy pursuing R&D activities related to hygienic coatings, including Ecolab, 3M, DuPont, Colgate Palmolive, Bayer, BASF, and Dow Chemical. Current leaders in the hygienic coatings market include Bionics GmbH and Agion Technologies.

**IMPARTING FUNCTIONALITY**

The special capabilities of functional coatings can be derived from the resins, additives, or both. Weaver notes that antimicrobial and photocatalytic coatings are examples where the effect is predominantly achieved through additive technology, while superhydrophobic coatings typically derive their properties from the resin structure. Shim also notes that functionality may be determined by how the coating materials are applied to the surface and designed to interact with the surface, or even how the surface is organized or constructed. In general, though, according to Weaver, functionality relates to the characteristics of the exposed coating surface, and the resin system as the carrier will have an important role to play in terms of the durability of the coating, even if additives are directly responsible for the desired functionality.

One of the challenges in developing functional coatings relates to the fact that the amount of material is very limited—typically on the order of grams per square meter, according to Shim. “Not only is imparting the functionality a challenge, distributing this functionality homogeneously across
the entire surface can be difficult. On the other hand, functional coatings are quite valuable because they can have a very significant impact despite the fact that such little material is involved," she adds. Two very different examples of BASF technology used for functional coatings include electrocoat technology that provides for smoother and more consistent deposition on the front and back sides of metal parts used for automotive manufacturing and seed coatings that enhance water absorption, enabling faster and more consistent germination.

In many cases, more than one coating ingredient is required to achieve the desired functionality. "Good coatings need the right resin to deliver the majority of mechanical and surface properties, with additives to fine-tune ease of application, reduction of coating defects, and optimization of surface characteristics," says Wubbels. The company has, in fact, investigated optimum polymer-wax emulsion combinations that deliver enhanced abrasion and water resistance combined with increased weathering and dirt pickup resistance for DIY and industrial wood coatings. "Good resin-wax combinations eliminate and prevent challenges in coatings compatibility and recoatability, as well as blocking and film formation," he says.

BYK, meanwhile, has commercialized some, and is developing more, additives that provide anti-dirt pickup, self-cleaning, or easy-to-clean properties as well as characteristics such as antifingerprint, antigraffiti, antislip, and antistatic performance, according to Lassila. Functional products from Celanese include binders and additives for easy-to-clean and low maintenance coatings, as well as vinyl acetate ethylene (VAE) with built-in antimicrobial properties and VAE-based adhesives and coatings with good adhesion to difficult substrates, such as polyethylene, polypropylene, and polyurethanes.

Dow Coating Materials (DCM) has also focused on the development of binders with novel functional properties. In the architectural space, the company offers FORMASHIELD™ Binder Technology for the removal of pollutants (formaldehyde in particular) from indoor air, multi-substrate exterior coatings, deck and concrete restoration coatings, and liquid stain-repellent interior coatings. Functional products for industrial coatings from DCM include MAINCOTE™ IC Resins, which reduce unintended heat transfer in industrial spaces, and ACOUSTICRYL™ Resins for noise reduction through sound damping. "What’s particularly exciting about these latter technologies is that they are opening new doors for coatings applications because they are designed to replace non-coating materials, such as asphalt pads, fiberglass, and polyurethane foam," Insogna says.

LONGER-TERM FUNCTIONALITY

The types of functional coatings outlined above are just some of the possibilities that have been actively pursued. There are many more functional coating technologies under investigation, some of which are at very nascent stages of development. Farwaha points to transparent conductive coatings using single-walled carbon nanotubes for antistatic and window insulating coatings and electrochromic and thermochromic window coatings used to increase the energy efficiency of buildings as important technologies that are attracting growing attention. He also notes that photoluminescent or high visible light-reflective coatings for interior walls have the potential to improve the ambience of a room and convert the walls into a light source.

Further out in the future, functional coatings might be used to create intelligent surfaces that interact with the environmental or biological systems (such as nerves), according to Wubbels. He also notes that the next generation of self-healing coatings could be self-regenerating and self-optimizing quasi-biological systems, and flexible coatings that have the ability to generate energy while simultaneously providing corrosion protection are also a distant possibility. Concludes Lassila: "The types of functions that can be incorporated into coatings are limited only by our imaginations. Coatings may someday be able to remove odors, release fragrances, change colors, perform photosynthesis, etc. in response to various physical stimuli."