Cutting-edge Innovation by Japanese Firms **Case Study 2**

Environment-Serving Photocatalysts: TOTO Ltd.

By Hiroaki SHIMOMURA

Introduction

By absorbing ultraviolet rays contained in sunlight, photocatalysts have the effect of decomposing organic substances on the surface of materials and making the surface easier to wet with water. Such reactions enable photocatalyst-fixed materials to obtain a variety of effects such as antifouling, antifogging, antibacterial, deodorizing, air purification and water clarification. For this reason, photocatalysts are drawing strong interest as environment-serving technology.

Photocatalysis took the global spotlight in 1969 when the so-called Honda-Fujishima effect was announced. With the discovery of super hydrophilicity as a new effect in 1995, the field of application has significantly expanded. Currently, photocatalysts find wide applications, including interior and exterior building materials, paints, purifiers and daily necessities.

Of these applications, exterior materials occupy more than 50% of the photocatalyst market. The cutting-edge technology features self-cleaning and environmental (air) purification effects as it makes use of solar energy. Efforts are now being made to develop materials with stable durability. As an example, this report introduces a variety of effects of the photocatalyst coating HYDROTECT COLORCOAT ECO-EX (produced by TOTO OKITSUMO COATINGS Ltd.) and its contributions to the environment.

Photocatalyst Coating & Durability

As mentioned earlier, photocatalysts have strong oxidation power to decompose organic substances by absorbing ultraviolet rays. However, they decompose not only dirt and bacteria but also organic matter in material components. The effect causes no problem as long as components are not organic substances (in other words, inorganic ones) such as tiles. But they promote the decomposition of coated film itself and thus cause material degradation in such forms as film peeling and discoloration when coatings contain organic substances.

To slow down the pace of degradation, it is effective to curb the volume of photocatalysis. However, smaller volumes naturally lead to a lower photocatalytic effect. Not only to protect film coated with resin-based paintings but also to keep the sufficient photocatalytic effect, it can be considered effective to laminate a new barrier layer between the photocatalyst layer and the primary coating. In developing ECO-EX, a clear photocatalyst layer was formed above a colored layer, which functions as a barrier layer. This enabled the volume of photocatalysis on the surface to be boosted, thus improving its effect of environmental purification. Furthermore, use of a special resin that is capable of withstanding the decomposition power of photocatalysts resulted in achieving stronger resistance to weathering of the overall coating as a whole. A more detailed explanation is made below.

ECO-EX is made up of three layers – the primer (undercoat) immediately above the base material, the colored middle layer that concurrently functions as a barrier layer, and the top photocatalyst layer. Forming each layer requires no energy such as baking, with each one dehydrating and hardening at room temperature as shown in the pattern diagram *(Chart 1)*.

The top photocatalyst layer comprises solely an inorganic component to prevent the photocatalyst from decomposing and degrading the film itself. The colored middle layer is of a graded structure under which its organic component is distributed on the undercoat side and the inorganic component on the top layer side. With these components bonded together with the undercoat and the top layer, strong adhesive power has been achieved. In this way, ECO-EX firmly binds together the undercoat for securing firm adhesion to the base material, the middle layer that functions as barrier to photocatalysis and the top photocatalyst layer. Thus we call it an integrated structure.

With this structure, strong resistance to weathering has been achieved. The outcome of a sunshine weatherometer (SWOM) test, a popular weathering test, shows ECO-EX maintaining its initial appearance without any significant change under a condition equivalent to 20 years of outdoor exposure. This excellent resistance to weathering helps reduce the frequency of recoating, slashing coating costs and energy consumption as well as reducing the environmental load.

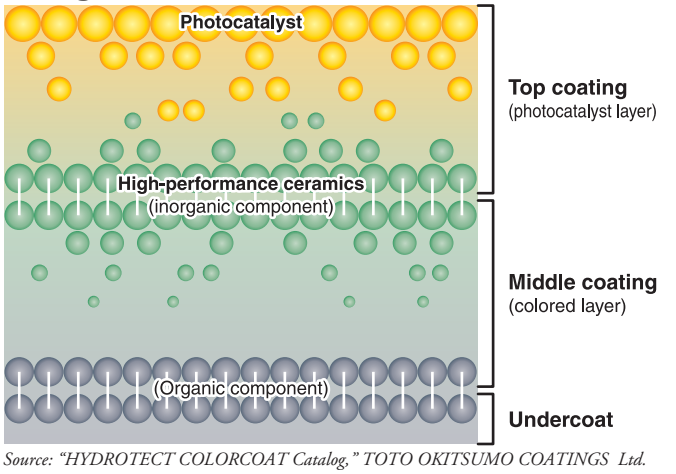
Effects of Photocatalyst Coating (Air Purification & Antifouling)

(1) Air-Purification Effect

With its strong oxidation effect, photocatalysts are capable of oxidizing nitrogen oxide (NOx) and other environmental pollutants in the atmosphere and attach them to the surface in the form of nitric acid

CHART 1

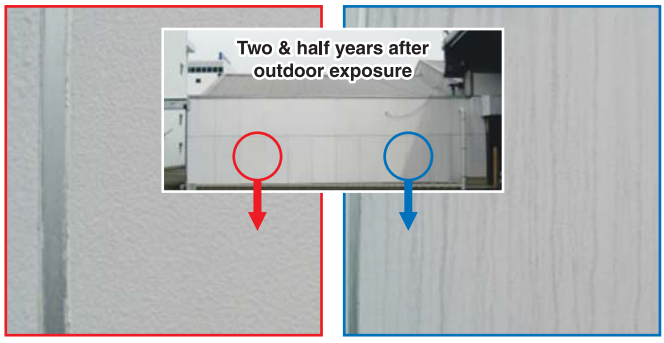
Integrated structure of ECO-EX



Source: "HYDROTECT COLORCOAT Catalog," TOTO OKITSUMO COATINGS Ltd.

CHART 2

Antifouling effect of photocatalyst coating



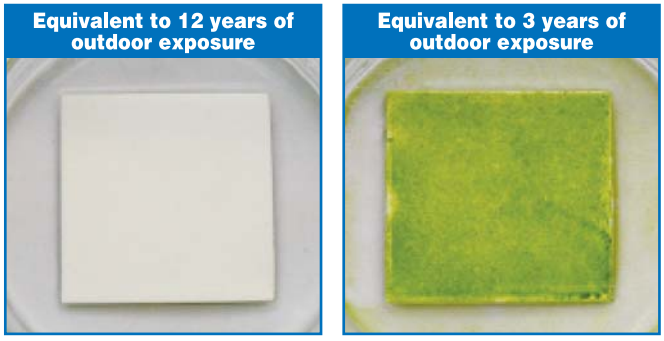
Wall portion coated with photocatalyst (ECO-EX)

Wall portion coated with conventional antifouling coating

Source: TOTO Ltd.

CHART 3

Anti-algae effect of photocatalyst coating



Photocatalyst coating (ECO-EX)

Coating with conventional anti-algae agent

Source: TOTO Ltd.

ions and other substances, thus having the effect of removing them from the air. To prevent pollutants from being unleashed in the air, it is effective to curb them when they are emitted from factories and automobiles. But once they are released in the air, it is extremely difficult to recover them, leaving us no choice but to rely on the mechanisms of natural depuration such as absorption, decomposition and deposition by way of plants and solar light. Photocatalyst materials, once set up in the environment, remove pollutants from the atmosphere on their own by utilizing sunlight without any injection of extra energy. The effect of such materials may be regarded as small from a broader viewpoint of the environment as a whole. However, photocatalyst materials can be construed as environmentally friendly. In particular, ECO-EX has greatly improved photocatalytic activity against NOx and other gaseous substances, with its environmental cleanup capability about six times as high as that of our company's conventional product under the same conditions.

(2) Antifouling Effect

Exterior taint is caused mainly by dust containing hydrophilic inorganic particulates such as earth and sand as well as by water-shedding organic substances contained in factory smoke and auto exhaust. Photocatalysts decompose organic substances contained in these pollutants and render the exterior surface super-hydrophilic, thus displaying high antifouling performance. The creation of the super-hydrophilic surface enables raindrops to infiltrate into a space between taint and the surface, push the taint up and wash it away with rainwater. As taint is naturally washed away by rainfall, the exterior can keep its original appearance for a long period of time without any maintenance work. This is called a self-cleaning effect. You can observe a drop of water on the surface of ECO-EX naturally spreading on the surface.

Chart 2 shows the results of an experiment in which two portions of the exterior wall of an actual building were covered with two different coatings – one part with ECO-EX *(left photo)* and the other with a conventional material *(right)*. Two and a half years later, you can see the ECO-EX portion maintains its clean appearance and the other portion is tainted with the remains of rain streaks.

Exterior taint also arises from the growth of fungi, algae and other microorganisms. Conventional coating materials contain anti-fungus and anti-algae agents so they may decompose microorganisms. Meanwhile, ECO-EX generates anti-fungus and anti-algae effects by taking advantage of the photocatalytic effect of decomposing organic substances. As time advances, the effect of anti-algae and other agents contained in conventional coating materials weakens because they gradually dissolve and flow out. But the photocatalyst enables the anti-fungus/anti-algae effect to be maintained over a long period as no elution occurs. *Chart 3* shows the outcome of an anti-algae test in which a conventional coating material was steeped in heated water to accelerate elution of agents. The conventional material lost its anti-algae effect in the equivalent of three years after the test while ECO-EX maintained its anti-algae effect for the equivalent of as long as 12 years, with absolutely no emergence of algae.

The antifouling effect has enabled regular cleanups for the maintenance of exterior appearance to be reduced substantially, sharply cutting the volume of detergents released into lakes, ponds and rivers, thereby leading to reduced water pollution.

Conclusion

Recently, numerous and various industrial products with photocatalyst technology have been put on sale to expand the market markedly. Efforts are being made actively to develop materials and composite structures which help the effective use of new photocatalysts like ECO-EX. However, the fast spread of photocatalysts has ended up in consumers finding it hard to obtain an appropriate evaluation of photocatalysts in products. To improve the situation, the Photocatalysis Industry Association of Japan was set up in 2006. Industry, academia and government have since worked together to standardize and set certification criteria for photocatalytic products with the aim of securing widespread use of highly reliable products. Currently, Japan is more active than other countries in the field of photocatalysis. It is hoped the domestic photocatalyst industry will develop further and that highly reliable information will be sent out from Japan in a stable way.

With regard to the practical use of photocatalysts, its self-cleaning effect on the exterior has been spotlighted. Today, however, photocatalysts are drawing renewed interest for their environmental cleanup effect amid growing public awareness of environmental problems like global warming. As introduced in this report, ECO-EX has enabled the environmental burden to be reduced with its improved self-cleaning and weatherproofing effects that have been attained through a review of the composition and structure of the photocatalyst coating. Also it is about six times more powerful than conventional products in the air-purification effect, enabling it to make greater contribution to the environment. We are determined to help resolve environmental questions as much as possible by trying to make our photocatalyst products even more effective. JS

Hiroaki Shimomura is an engineer, Technical Development Department, HYDROTECT Division, TOTO Ltd.