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ADVANCED REFLECTOR TECHNOLOGY FOR IN-VEHICLE UV DISINFECTION SYSTEMS

Ultraviolet disinfection systems can make vehicles cleaner and safer for occupants. With interest in the approach on the rise, equipment makers need to improve the performance and longevity of their solutions. An innovative reflector technology can help them meet both objectives, says Dr. Stefan Ziegler, Head of Research & Development at Alanod.

The COVID-19 pandemic is encouraging automakers and their suppliers to explore novel filtration and disinfection technologies. Their aim is to reduce the risk of pathogen transmission in cabin air, or from contact with contaminated surfaces within the vehicle. One technology that offers significant potential in the sector is the use of short-wavelength ultraviolet (UV) light. UV radiation is deadly to bacteria and viruses: UV photons can break DNA and RNA bonds, rapidly inactivating the microbes.

UV disinfection systems for automotive and transportation applications come in two distinct forms. High-power UV emitters can be integrated into cabin HVAC systems to destroy microbes in incoming or recirculated air. Alternatively, UV emitters can be incorporated into cabin lighting and used when the vehicle is unoccupied to destroy pathogens on interior surfaces. The latter approach has already been used successfully in the healthcare sector to eliminate pathogens in ambulances.

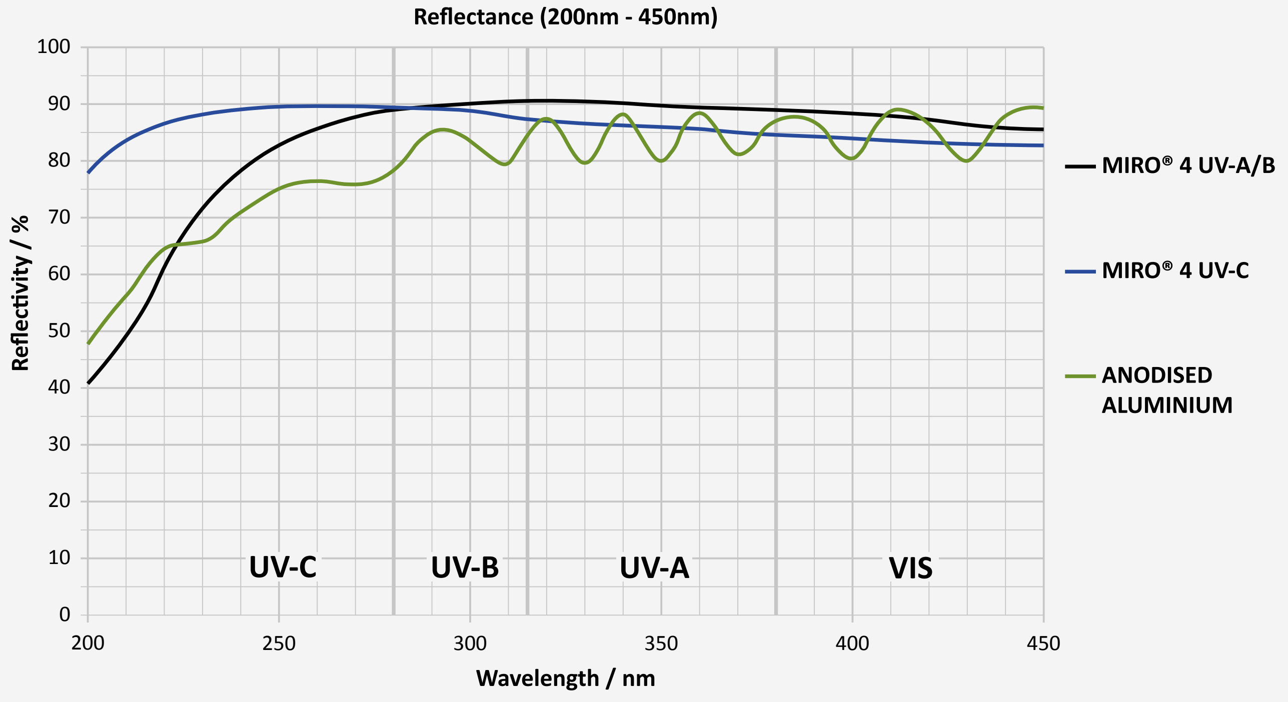

Fig.1 - The UV reflectivity of anodised aluminium can vary by as much as 10%

Reflecting on UV sterilisation efficiency

One challenge for designers of UV air sterilisation systems is that microbial particles make up only a tiny fraction of the overall air volume flowing through them. Such systems must take steps to maximize the probability of a UV photon interacting with a bacterial cell or virus particle. Typically, that includes the use of filters upstream of the UV element to screen out larger particles of dust and dirt. The majority of UV sterilization applications also rely on efficient reflectors to direct the light evenly throughout the air volume to be treated, and to give photons multiple chances to hit their target.

Many materials that are highly efficient reflectors of visible light perform poorly at UV wavelengths. Polished stainless steel, for example, reflects only around a quarter of incident UV-C radiation. Fortunately, there is a material that offers much higher reflectivity at UV wavelengths, while also being robust, cost-effective and easy to fabricate. That material is aluminium.

A conventional anodised aluminium surface will reflect more than 80 percent of incident light at UV wavelengths. That's a three-fold improvement over stainless steel, but surface innovation engineers at Alanod have found a way to do even better.

The key to our approach is a technology that turns a limitation of standard aluminium reflectors into a strength. As the graph in figure 1 shows, the UV reflectivity of anodised aluminium varies by as much as 10 percent depending on the exact wavelength of the incident light. That phenomenon is the result of interference effects. When UV light hits an anodised surface, part of the light is reflected from the material's oxide layer and part is reflected from the pure aluminium beneath the anodised surface. Those two reflections interact, effectively boosting reflectivity at some wavelengths and reducing it at others.

Using conventional surface treatment techniques this interference effect is impossible to control. The oxide layer on an anodised surface will vary in thickness, and it will grow over time as the material reacts with oxygen in the environment.

Nanoscale surface technology

To create a new generation of UV-reflective materials, we needed to find a new way to add a protective surface to pure aluminium. Our scientists looked for a technology that would allow us extremely precise control of the surface layer, so we could control the interference effects and boost reflectivity where it would be most useful.

The approach we have adopted is plasma-enhanced chemical vapour deposition (PECVD). This technique uses an energetic plasma to deposit material onto a surface at lower temperatures than conventional physical vapor deposition methods. For Alanod's new MIRO® UV products, the material deposited is a precisely controlled silicon oxide layer around 100nm thick, on top of a base layer of very pure aluminium.

Because the new process gives us much greater control over the thickness of the surface layer, it lets us tune the performance of our materials to specific UV wavelengths. MIRO® UV A/B offers UV reflectivity of more than 90 percent at wavelengths of 300 to 350nm, while MIRO® UV C is designed to deliver a peak of well over 90 percent at the 250nm wavelength used most commonly in disinfection and sterilization applications.

Double the durability

PECVD technology offers another major advantage for the production of UV-reflective materials: greatly enhanced durability. Intense UV light creates demanding conditions for surface coatings, generating large numbers of charged particles that can greatly accelerate normal oxidation processes. Conventional anodised materials are highly durable in most applications because their surfaces exhibit "self-limiting" properties.

The layer of aluminium oxide on the surface initially grows, but eventually stabilises as the remaining exposed pure aluminium is converted to oxide. In UV equipment, however, oxidation continues through the life of the equipment; eventually requiring components to be replaced as their reflectivity falls.

The silicon surface of MIRO® UV materials, by contrast, has extremely low porosity, creating an effective barrier against oxygen ions. In intensive tests in a high temperature, high humidity environment, MIRO® UV exhibited a change in reflectivity of less than 1 percent after 1000 hours.

In the absence of methods for the accelerated testing of UV reflective materials, we can't predict exactly how long our products will last, but we are confident of a lifetime at least twice that of conventional aluminium reflectors. For vehicle owners, that could significantly reduce the cost and disruption caused by the need to periodically replace reflectors.

Engineered for versatility

Below the PECVD surface coating, the MIRO® UV material range is built upon other layers of innovative engineering, designed to increase performance, durability and ease of use for manufacturers. The reflection layer consists of a 99.99% pure aluminium layer which provides the maximum reflectivity. The base material under this layer is anodised aluminium. The anodic coating is optically inactive but provides a high surface strength, allowing ease of handling and cleaning.

The material can be delivered either with a polished mirror-like surface for applications requiring precise control of the angles of reflection, or a matt finish that improves the distribution of reflected light in HVAC ducts and other similar applications. The substrate is aluminium and so can be easily recycled when replaced.

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Whether it is used to maintain system performance or improve the safety and quality of interior air, ultraviolet light is set to become an important element of vehicle interior design and automotive HVAC technologies.

With its new MIRO® UV product range, Alanod provides equipment makers with simple and effective ways to boost the performance, reliability and longevity of their equipment.

For more information about UV solutions or for technical advice, please visit www.alanod.co.uk

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