Nanotechnology-Enhanced Anti-Fogging and Anti-Reflection Solution for Improved Automotive Sensing

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Dexerials Corporation

Nanotechnology-Enhanced Anti-Fogging and Anti-Reflection Solution for Improved Automotive Sensing

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Abstract: Advancements in automotive cameras and LiDARs are crucial for enhancing the sensing capabilities of autonomous driving. A significant challenge in this domain is the signal degradation caused by fogging and reflections on the sensor cover surfaces. Traditionally, heaters and anti-reflection treatments have been used to mitigate these issues. Dexerials Corporation has developed an innovative solution that integrates both anti-fogging and anti-reflection properties utilizing its proprietary nanofabrication and formulation technology. This approach is anticipated to enhance sensing accuracy while reducing energy consumption by eliminating the need for heaters.

Keywords: Anti-fogging, Water absorption, Hydrophilic, Hydrophobic, Anti-reflection, Film, Moth-eye, nanofabrication, imprinting, automotive, sensing, cameras, LiDAR

Introduction

Within the ADAS and AV industry there is consensus that different sensor types are required components of sensor suites for high level of autonomy. Cameras and LiDARs are vital for autonomous driving. A standard car configuration includes a windshield in front of the camera. In the case of LiDARs, the optics of the LiDAR system are covered with a protective window that not only protects but also allows LiDAR to function correctly by letting light pass through without significant distortion. The incoming light reflects off the surface of the windshield and LiDAR cover window, reducing light transmittance.

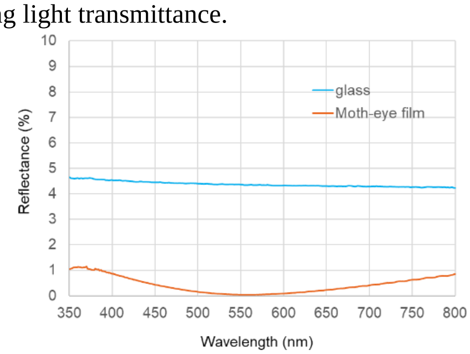

Figure 1. Comparative surface reflectance from Moth-Eye Film and glass substrate (1.1mm-crown glass). The samples were prepared with black tape attached to the back of both substrates to isolate reflection from the front surfaces

Dexerials has developed the moth-eye type anti-reflection film using its own microfabrication technology and has already proposed it as a solution to minimize reflections, glare and ghosting. Figure 1 compares surface reflectance from the moth-eye film and glass substrate.

During actual vehicle operation, however, the outside temperature may drop, causing condensation on the glass and resulting in fogging. When condensation causes fogging, the light gets scattered, resulting in degradation of the signal received by the cameras or Lidars. To prevent fogging on the glass or sensor covers, especially in environments with varying temperatures or humidity, heaters are commonly employed. In this paper, we suggest a solution that integrates low reflection and anti-fogging capabilities by designing a moth-eye surface with water-absorption-based anti-fogging functionality.

Proprietary nanofabrication technology

Nanofabrication. Dexerials's moth-eye type anti-reflection film with tiny surface structures smaller than the wavelength of visible light (from 380 to 780nm) mimic the natural moth eye pattern, minimizing reflections and enhancing optical clarity.

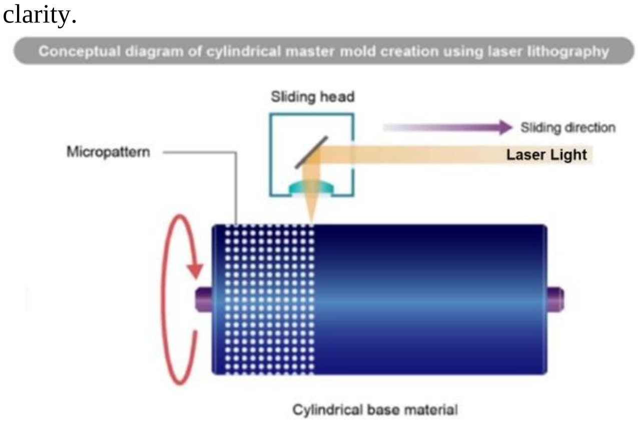

Figure 2. Fabrication of cylindrical mold

Dexerials's method for creating the moth-eye structure is based on the same technology originally employed in Blu-ray discs and semiconductors. In this method, holes (pits), that form the foundation of moth-eye structures, are initially created on a master roll using laser lithography technology. Subsequently, the formed pits are transferred onto the film substrate during nanoimprinting process. The precise control of the irradiation angle and laser beam position by a computer allows desired design of microstructure patterns. *Master roll (cylindrical mold).* Dexerials has two ways to create the master molds used in transferring micro/nano structure patterns onto film substrates – lithographic processing and precision machining. Lithographic processing is a preferred technique for creating moth-eye patterns due to its high resolution and precision. Figure 2 illustrates the process of creating microstructure patterns on a cylindrical base material using laser imaging in lithographic processing.

Nanoimprinting. Dexerials nanoimprint technology is a roll-to-roll process for continuous replication of nanostructures by pressing the cylindrical master mold with the inverse of the desired nanoscale pattern into the UV-curable polymer dispensed on a film substrate. As the base film passes under the master mold, the polymer with transferred nanostructures is then cured by UV light to retain the pattern. See Figure 3.

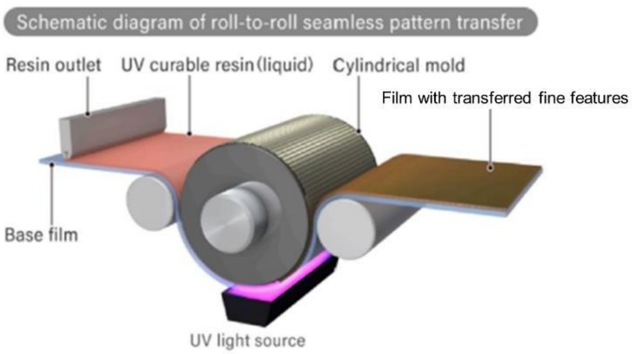

Figure 3. Method of nanoimprinting

Integration of both anti-fogging and anti-reflection properties

Anti-fogging. Fogging occurs when water vapor in the air condenses into tiny droplets on a surface, forming a layer that scatters light and obstructs clear visibility. To prevent fogging, it is necessary to prevent condensation on the surface of the substrate. There are several common anti-fogging methods. *Hydrophilic coatings* form a thin layer on the surface instead of forming droplets. Advanced materials based on *water absorption* are engineered to absorb moisture and prevent fogging through innovative structural and material properties.

Dexerials is developing products with anti-fogging properties based on *water absorption*.

Fabrication of anti-fogging moth-eye film. A moth-eye film was manufactured in a roll-to-roll nanoimprinting process using a UV-curable polymer with water absorption properties. Tri-acetyl cellulose (TAC) film was used as the base film. The samples' structure is shown on Figure 4 including anti-fogging moth-eye layer, TAC film, adhesive layer, and glass. Reflectance and transmittance were measured with the angle of incident light set at 5°. The anti-fogging moth-eye film exhibits similar properties to the properties the moth-eye film we previously reported. It has lower reflectance and higher transmittance than the glass substrate.

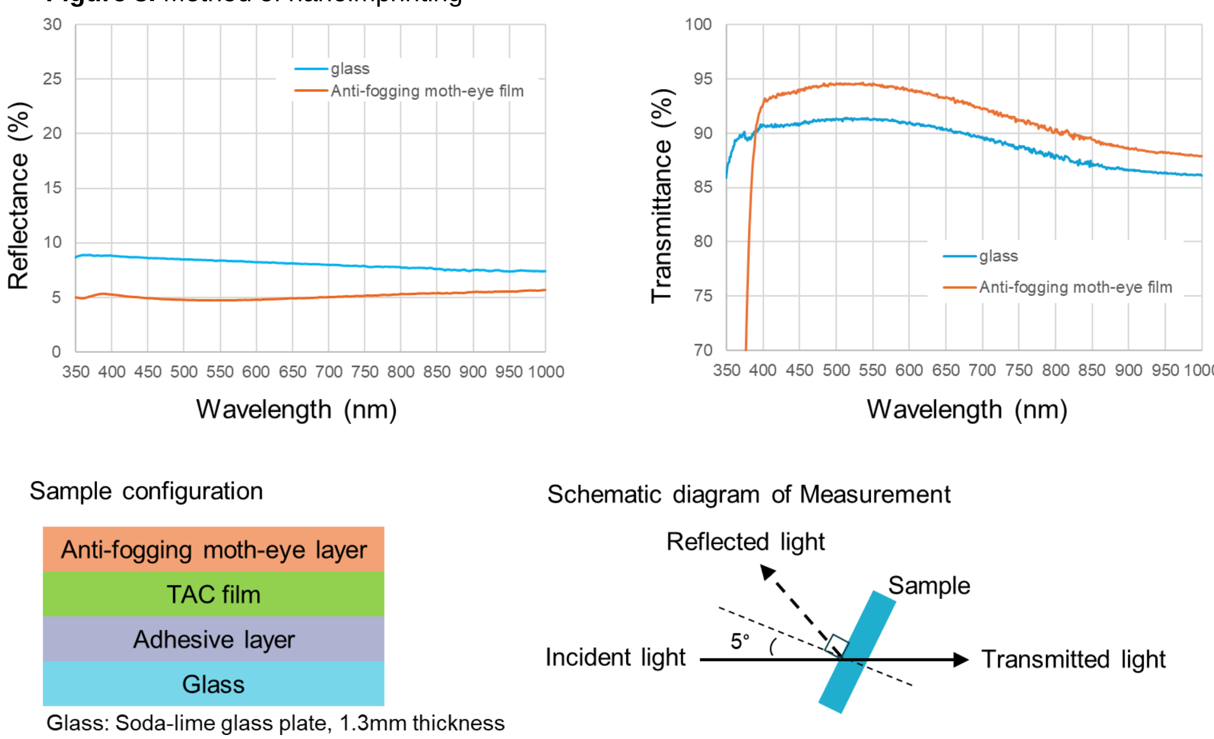

Figure 4. Reflectance and Transmittance of Anti-Fogging Moth-Eye Film

Angular dependence of reflectance of Anti-fogging moth-eye film. In a vehicle, the windshield is disposed in a tilted position in front of the forward monitoring camera. Therefore, information on the angle dependance of the reflectance is crucial. Figure 5 below shows how the reflective properties of the anti-fogging moth-eye film and glass substrate change as the angle of incidence varies. A black tape was attached to the back of the sample to prevent reflection from the back side of sample. The reflectance of the anti-fogging moth-eye film is lower than that of glass at all angles of incident light.

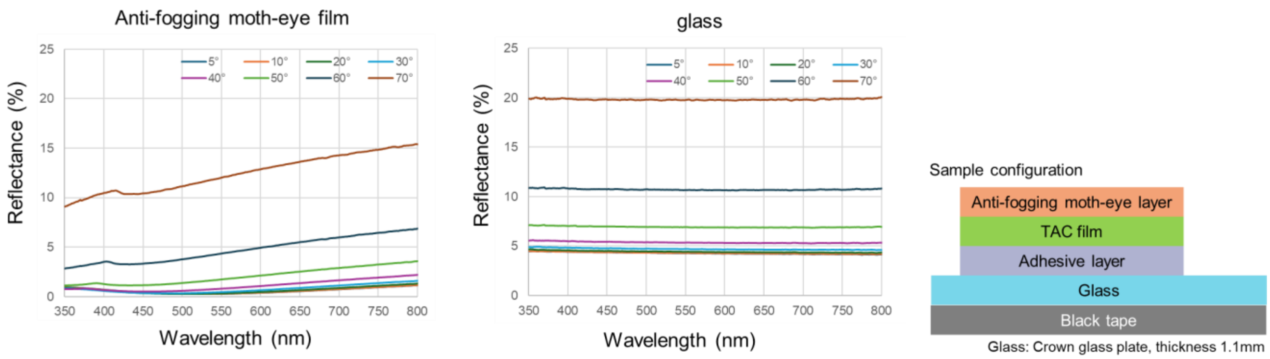

Figure 5. Angular dependance of the reflectance

Anti-fogging performance. Anti-fogging properties are evaluated using a 40°C-steam test. As shown in the figure 6, the sample is positioned above the opening in a window in thermostatic water bath heated to 40°C. Measurements are performed at the surrounding temperature 23±3°C. The sample is placed on the window for 30 seconds, and pictures are taken every 10 seconds to check for fogging. This procedure helps assess the anti-fogging properties of the material. The sample structure for a steam test is shown on Figure 6, where the anti-fogging moth-eye film is adhered in the center of glass substrate. Immediately after placing the sample above thermostatic water bath, the glass area becomes cloudy. On the other hand, the anti-fogging moth-eye coating in the central part of the glass exposed to steam at 40°C, demonstrates its ability to resist fogging even after 30 seconds.

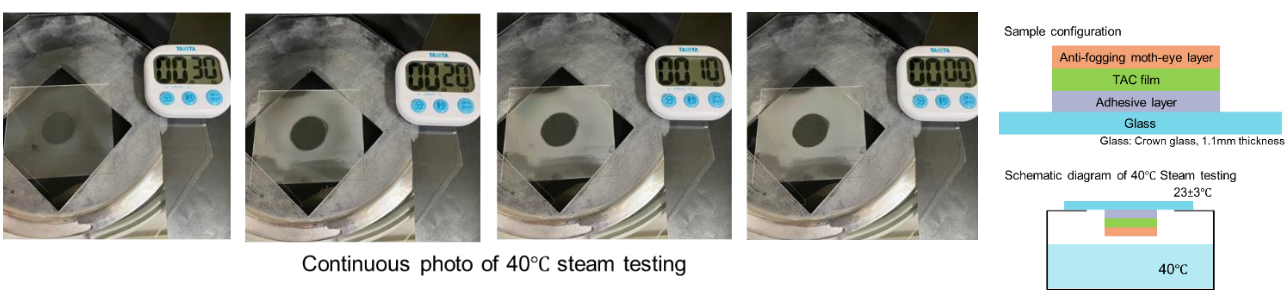

Figure 6. 40℃ steam testing method

Reflective properties of the moth-eye film with absorbed water. We investigated whether the low reflectance characteristics of the moth-eye film could be preserved while adding the anti-fogging material function. The sample configuration for measurements was the same as that shown in Figure 5. The sample was immersed in water for a duration of two hours to allow sufficient water absorption. Subsequently, we measured the reflectance immediately after removing the sample from the water. We compared the measured data to the data obtained before submersion, immediately after removal from water, and after two hours in an air-conditioned environment. Additionally, we compared it with the measurement data for glass. After removing the sample from water, we observed a slight increase in reflectance compared to the initial sample.

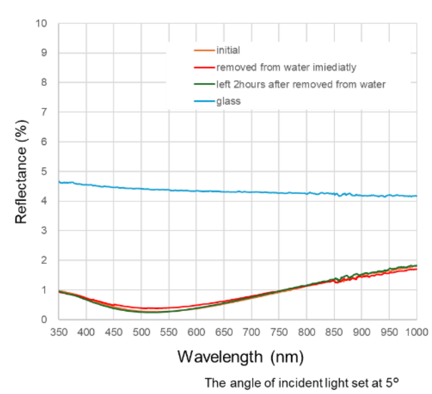

Figure 7. Reflection property of the film with absorbed water

However, the low reflectance characteristics were maintained when compared to glass. Additionally, a sample left in an air-conditioned environment for two hours, closely followed the initial reflectance curve, returning to its original state. The anti-fogging moth-eye film consistently maintains its low reflection properties even when it absorbs water, and it reverts to its original state after drying.

Surface properties of Anti-fogging Moth-eye film. The surface of the anti-fogging moth-eye film is water-repellent. Initially, Per- and Polyfluoroalkyl Substances (PFAS) were used as surfactants to achieve the water-repellent property. However, due to growing global regulations surrounding PFAS, we are actively researching alternative methods to create water-repellent surfaces without relying on PFAS-based materials. Figure 8 illustrates that the transmittance of anti-fogging moth-eye film exceeds that of glass regardless of PFAS usage. Both materials exhibit similar transmittance curves. Additionally, we measured contact angles of the two materials with water, resulting in values of 135° and 131°, respectively.
Going forward, we will explore how these differences in contact angle impact performance.

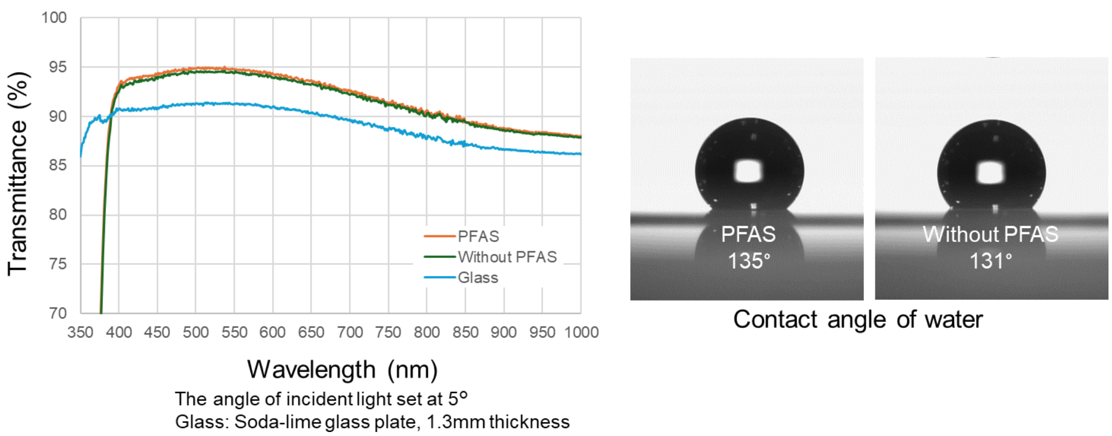

Figure 8. Properties of anti-fogging month-eye film with and without PFAS

Comparison of anti-fogging moth-eye film with conventional moth-eye film. Figure 9 presents a comparison of the reflectance data between conventional moth-eye film and the newly developed anti-fogging moth-eye film. The sample configuration is identical to that of Figure 5. The graph indicates that the reflection curves of both moth-eye films are nearly indistinguishable, demonstrating comparable levels of performance. Furthermore, the anti-fogging moth-eye film exhibits a significantly lower reflectance curve relative to that of standard glass.

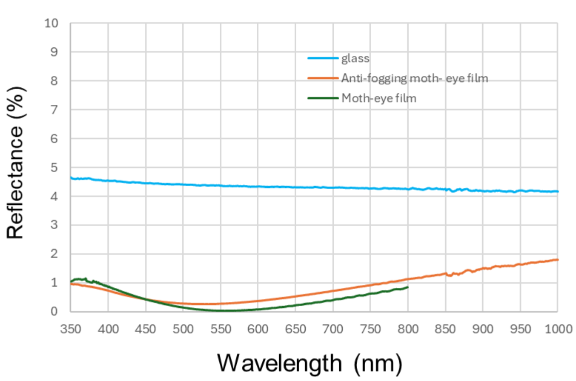

Figure 9. Comparison of Anti-Fogging Moth-Eye film with conventional Moth-Eye film

Conclusion

It’s possible to achieve both anti-reflective and anti-fogging properties simultaneously. By combining Dexerials proprietary nanofabrication techniques for anti-reflection properties with formulation technology for anti-fogging, a single multifunctional solution can be created. Unlike heaters, the anti-fogging moth-eye film doesn’t require electricity, making this solution particularly promising. As a result, it is anticipated that the described solution can achieve both enhanced sensing accuracy and reduced power consumption simultaneously.