Characterization of Anti-Sparkle Film for Automotive Applications

Paul Weindorf, Brian Hayden, and Kong Lor

Visteon Corporation, Michigan, USA

Abstract

The amount of sparkle associated with automotive anti-glare display surfaces is generally worsened with increasing display resolutions. One sparkle countermeasure recently introduced by 3M is the use of an anti-sparkle optically clear adhesive (OCA). The reflection properties of the 3M anti-sparkle OCA are further investigated.

Author Keywords

Anti-glare; anti-sparkle; sparkle; reflection; optically; OCA

1. Introduction

Anti-glare (AG) surface treatments are often utilized on automotive displays in order to minimize specular reflection components by scattering the rays from the light sources as shown in Figure 1-1.

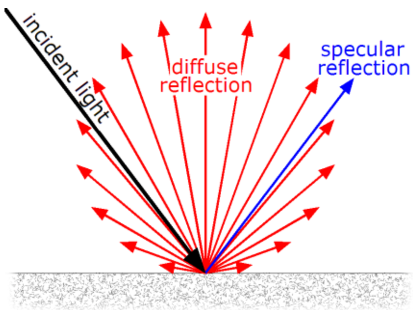

Figure 1-1. Diffuse Reflection from Anti-Glare Surface [1]

The use of AG surface treatments may cause a sparkle phenomenon often described as a grainy or scintillating effect when used in conjunction with a display. Sparkle is caused by the "randomized light refraction coupled with the pixel orientation that leads to non-uniform lighting" [2] as shown in Figure 1-2.

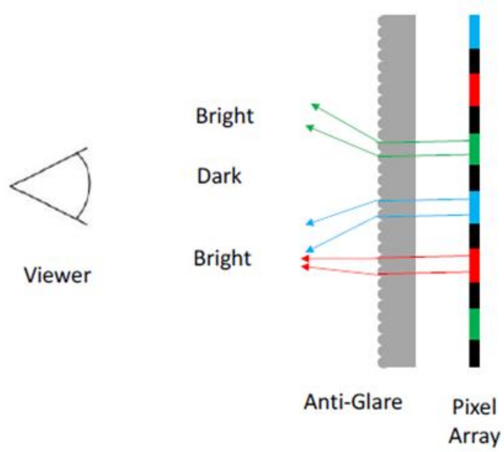

Figure 1-2. Light rays leaving the pixel array demonstrating how sparkle is produced [2]

Most current attempts to reduce sparkle have concentrated on reducing the size and pitch of the anti-glare surface features as shown in Figure 1-3.

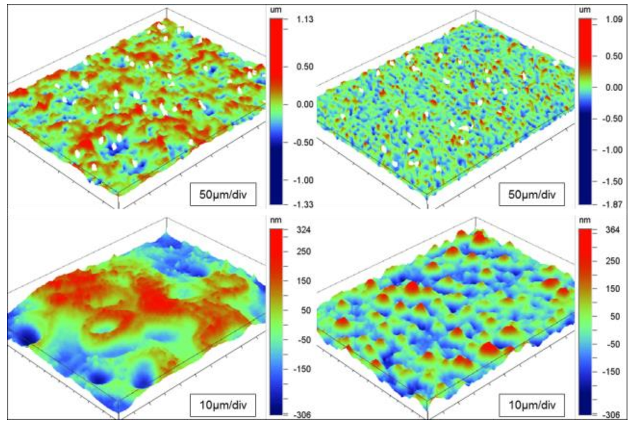

Figure 1-3. Wyko 3D Surface Analyses - High Sparkle (Left), Low Sparkle (Right) [3]

3M has developed a unique anti-sparkle (AS) optically clear adhesive (OCA) film that uses a diffraction grating structure between the display and the anti-glare cover lens as depicted in Figure 1-4.

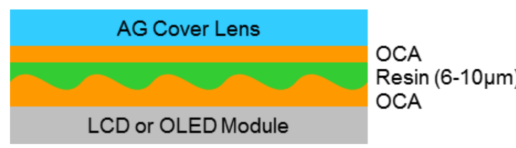

Figure 1-4. Anti-sparkle Film Diagram [Courtesy of 3M]

The 3M AS OCA is based on a 2-dimentional diffraction grating approach that essentially replicates the light from each sub-pixel into nine equally illuminated dots as shown in Figure 1-5.

Figure 1-5. Individual light dot multiplied by 2-dimensional anti-sparkle grating [Courtesy of 3M]

Although the 3M AS OCA does a great job of significantly reducing sparkle, there are other optical consequences that need to be understood. 3M wrote a helpful paper [2] that addressed most of the optical effects associated with the use of the 3M AS OCA:

- Sparkle Reduction – Showed significant reduction, but did not address effect as a function for distance from the display
- Gloss – the AS film causes a reduction in the gloss level
- Image Sharpness – the AS film reduces image clarity, but generally in the area of acceptability.

One area that the 3M paper [2] did not address is the reflection performance of the AS film. Although decreased gloss is an indication that the reflection performance is changing, gloss is not a direct indicator of the reflection performance. As displays are utilized more often in automotive applications, the importance of being able to see the display presentation under various lighting conditions becomes important [4]. Generally AG surfaces are used to minimize reflection components from specular (mirror image) sources such as white shirts and to reduce the image sharpness of the specular sources so that they are less recognizable. Although AG surfaces help reduce specular source reflections from objects like white shirt, seats and the like, AG surfaces always increase the amount of reflection from direct sun light illumination due to their scattering properties. It is important to recognize that automotive “cockpit geometry designs must never allow direct specular reflection of the sun by the user that may result in retinal damage and/or momentary blindness” [4]. Therefore, based on the geometry in the vehicle, only the reflected haze component from direct sunlight illumination needs to be considered. Although the AG surface is the main light scattering element, other elements such as the 3M AS OCA needs to be considered. Since the diffractive grating structure requires an index of refraction mismatch for operation, additional reflections may be expected and are the subject of this investigation.

2. Background/Objective

The objective of this paper is to measure the reflection performance of the 3M anti-sparkle OCA film under direct sun lighting conditions (collimated lighting) and to make an assessment of the increased reflection seen by the user.

The sample configurations measured are depicted in Figures 2-1. The moth-eye configurations were included to eliminate rear surface reflections so as to mimic optical bonding to a display.

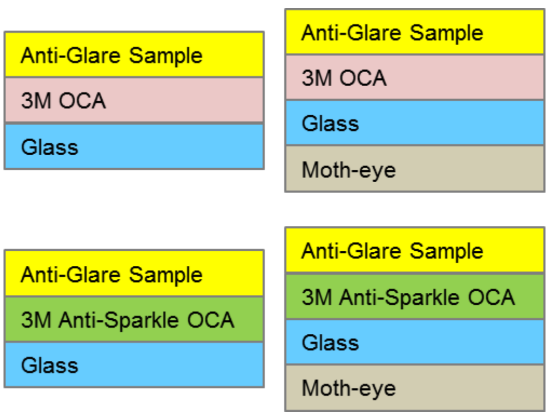

Figure 2-1. Optical Sample Configurations

The various materials in the optical samples were:

- AG film HM01 – Mitsubishi super extra minute AG
- AG film LM302 – Clear version of Bayer LM296 tinted film
- AG film M01 – Mitsubishi minute AG
- AG film HM02 – Mitsubishi extra minute AG
- 3M Anti-Sparkle OCA film – Easy 160829-5x7
- 3M OCA – 8146-5
- Glass – 3mm soda lime type
- Moth-eye – Dexerials MS-ME-331 25µm

3. Measurement Results

The various optical measurements collected on the test samples were:

- Table 3-1 – *HunterLab UltraScan:*
    - Specular Component Included (SCI)
    - Specular Component Excluded (SCE)
    - Haze per ASTM D 1003-07 Method B [5]
- Table 3-1 – Gloss (60°) using BYK micro-TRI-gloss
- Figures 4-1 - 4-11 – Reflectance Distribution Function (RDF) using a Display Messtechnik SMS-1000 system

Table 3-1. SCI, SCE, Haze and Gloss Measurement Data

ID	SCI	SCE	Haze	Gloss
Glass	8.13	0.02	0.1	152.0
HM01 | OCA	8.28	0.20	0.8	141.0
HM01 | AS OCA	8.44	2.26	52.4	95.2
Difference	*0.16*	*2.06*	*51.6*	*-45.8*
HM01 | OCA | ME	4.55	0.18	0.9	102.3
HM01 | AS OCA | ME	4.70	0.39	52.3	88.8
Difference	*0.15*	*0.21*	*51.4*	*-13.5*
HM02 | OCA	8.24	1.25	5.7	89.4
HM02 | AS OCA	8.42	3.16	52.7	67.1
Difference	*0.18*	*1.91*	*47.0*	*-22.3*
HM02 | OCA | ME	4.57	1.03	5.6	67.2
HM02 | AS OCA | ME	4.67	1.19	53.2	61.7
Difference	*0.10*	*0.16*	*47.6*	*-5.5*
LM302 | OCA	9.09	3.96	21.4	36.9
LM302 | AS OCA	9.25	5.72	60.1	26.5
Difference	*0.16*	*1.76*	*38.7*	*-10.4*
LM302 | OCA | ME	5.40	3.12	21.3	27.4
LM302 | AS OCA | ME	5.57	3.47	60.2	23.3
Difference	*0.17*	*0.35*	*38.9*	*-4.1*
M01 | OCA	9.01	4.42	27.8	29.7
M01 | AS OCA	9.20	5.80	60.4	23.4
Difference	*0.19*	*1.38*	*32.6*	*-6.3*
M01 | OCA | ME	5.35	3.38	28.3	22.3
M01 | AS OCA | ME	5.54	3.58	60.5	21.3
Difference	*0.19*	*0.20*	*32.2*	*-1.0*

To gain a sense of the sparkle improvement provided by the 3M AS OCA, Figure 3-1 shows a dramatic reduction in sparkle as measured by the Display Messtechnik SMS-1000. Generally sparkle values less than s’=0.014 are considered acceptable.

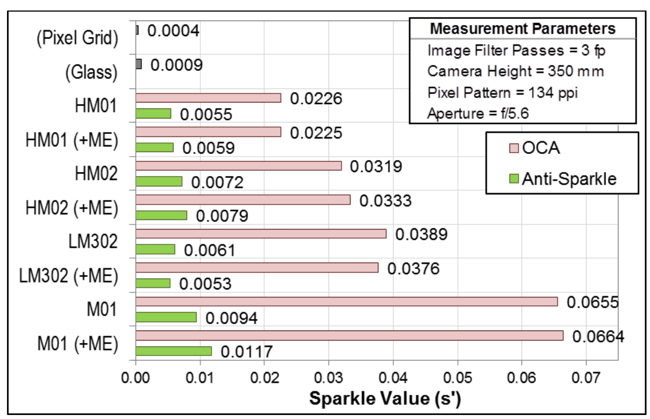

Figure 3-1. Display Messtechnik SMS-1000 Sparkle Measurements

4. Analysis

The SCI total reflectance results in Table 3-1 show that the 3M AS OCA contributes very little to the overall reflection rate and is on the order of 0.1% to 0.19%. However what is very interesting is that the amount of light scattering capability is impressive as seen by the percentage of haze increase with the 3M AS OCA.

For instance, with the shiny (minimal AG) HM01 film, the 3M AS OCA is scattering the light to result in a haze value of over 50%! As a result of this light scattering attribute, some interesting results occur for the SCE values which are a measurement of the reflected light that is scattered away from the specular direction. As can be seen by the shiny HM01 film, when the rear surface of the sample is allowed to reflect, about 2% of the total 4% rear surface reflection is scattered. Therefore if scattered reflected light is not desired, either rear surface optical bonding or an engineered air gap with anti-reflection films is required.

However if an “AG” appearance is desired, the 3M AS OCA may be utilized to scatter the reflected light by controlling the percentage of rear surface reflection without substantially affecting image clarity and sparkle as is normally the case with AG films. Sometimes this light scattering is desired to make the reflected object edges less visible.

The Reflection Distribution Function (RDF) which measures the reflectance as a function of angular offset from the specular angle is useful to understand the scattering profile of the incident light. The scattering profile of a piece of black acrylic is shown in Figure 4-1 where as expected a high specular component with low haze tails is obtained. However it was discovered that the specular component of the black acrylic behind the measurement sample reflects the light scattered by the 3M anti-sparkle OCA film and therefore the RDF results were not representative for a sample that would be optically bonded to the display. The reflected specular component behind the sample resulted in RDF tails that were excessively high due to the scattering nature of the 3M anti-sparkle OCA film. Therefore to reduce the specular reflection behind the sample, moth-eye film was laminated to the black acrylic as shown in Figure 4-2 with an accompanying reduction in the specular peak as shown in Figure 4-1.

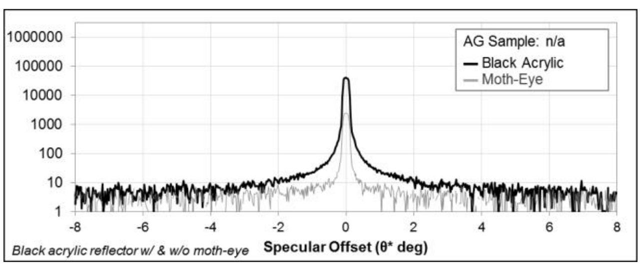

Figure 4-1. SMS-1000 RDF for Black Acrylic

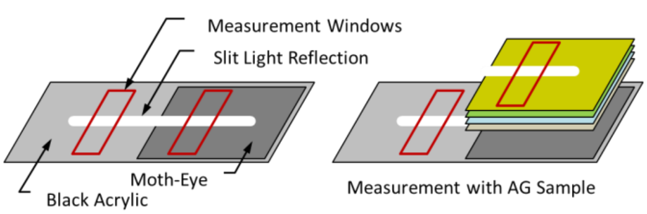

Figure 4-2. Moth-eye added to measurement area to reduce specular reflections

The RDF's for the various films tested per Figures 4-3 through 4-6 show the that 3M AS OCA adds very little to the haze tails when the light is absorbed behind the sample as is typical for optically bonded configurations .

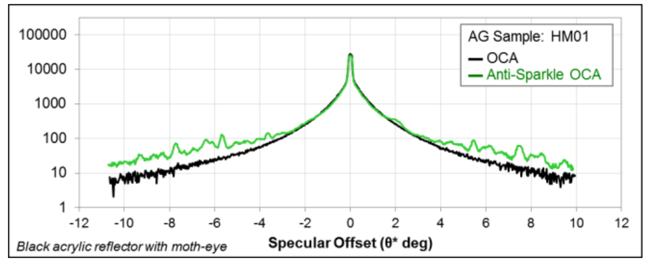

Figure 4-3. RDF of HM01 with and without 3M AS OCA.

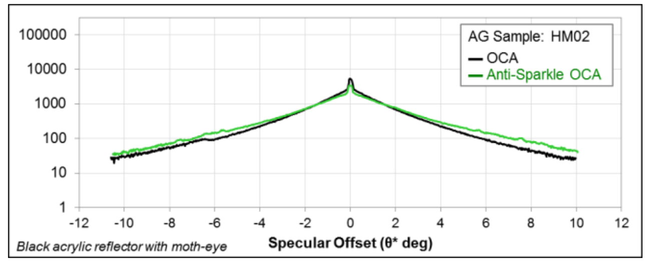

Figure 4-4. RDF of HM02 with and without 3M AS OCA.

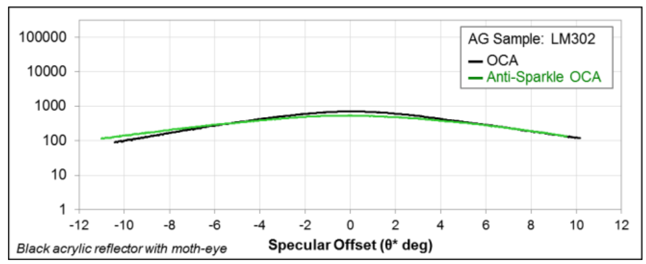

Figure 4-5. RDF of LM302 with and without 3M AS OCA.

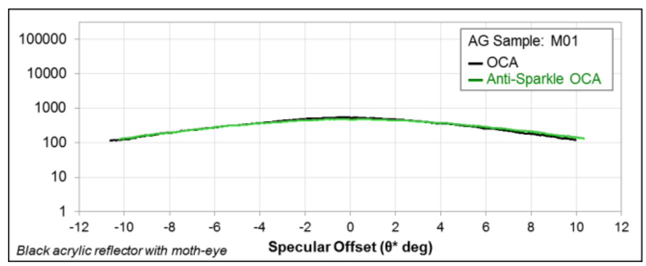

Figure 4-6. RDF of M01 with and without 3M AS OCA.

To help understand why it is important to laminate moth-eye film on the black acrylic to make it appear more of a complete light absorber, Figure 4-7 shows the result without moth-eye on the black acrylic corresponding to Figure 4-3 which has the moth-eye laminated on the black acrylic. As would be expected, the increase in the diffuse tails is most notable on the more shiny (i.e. higher gloss) AG surfaces such as the HM01. Due to light scattering of the 3M AS OCA combined with the specular reflection of the black acrylic without the moth-eye behind the sample, the RDF tails increase substantially for the shiny HM01 surface.

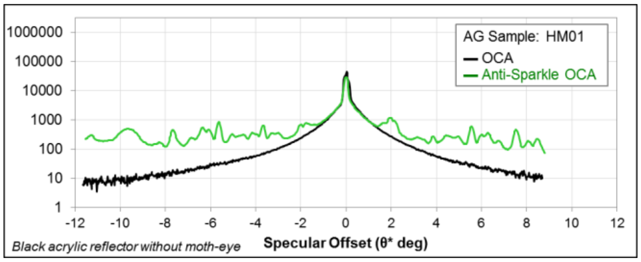

Figure 4-7. RDF of HM01 with and without 3M AS OCA.

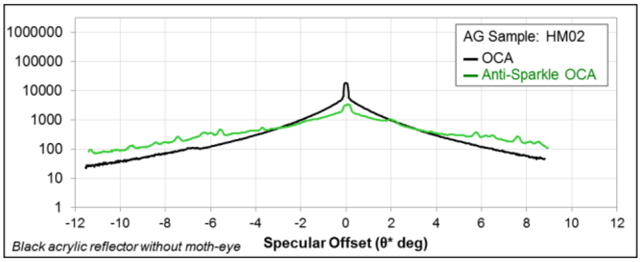

Figure 4-8. RDF of HM02 with and without 3M AS OCA.

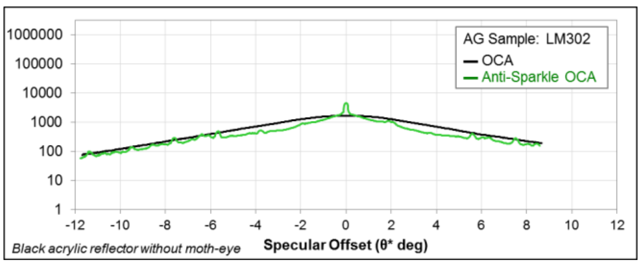

Figure 4-9. RDF of LM302 with and without 3M AS OCA.

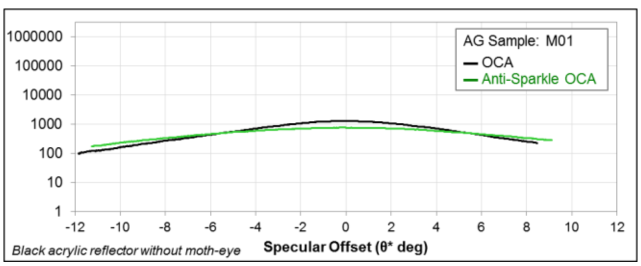

Figure 4-10. RDF of M01 with and without 3M AS OCA.

Figures 4-8 through 4-10 show that as the gloss level is decreased (i.e. more scattering from the AG surface), the scattering caused by the 3M anti-sparkle film becomes less dominant.

As expected, if the moth-eye is also removed from the rear side of the measurement sample, the haze tails increase in magnitude as shown in Figures 4-11a, 4-11b.

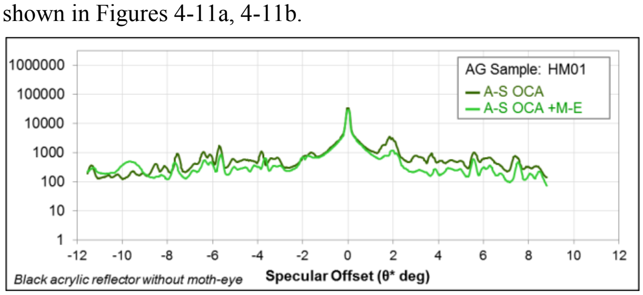

Figure 4-11a. RDF of HM01 with 3M AS OCA, with and without rear moth-eye.

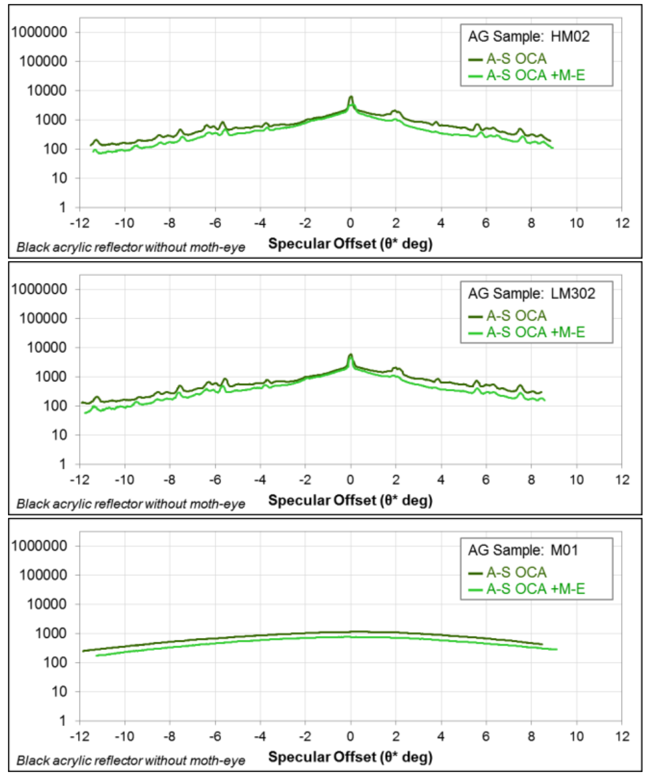

Figure 4-11b. RDF of HM02, LM302, M01 with 3M AS OCA, with and without rear moth-eye.

5. Conclusion/Summary

The SCI total reflectance results show that the 3M anti-sparkle OCA contributes very little to the system reflectance and is on the order of 0.1% to 0.19%. However due to the light scattering properties of the 3M anti-sparkle OCA, it is important to use an optically bonded or engineered air gap system in order to reduce the reflected haze component. The 3M anti-sparkle OCA significantly reduces image sparkle while maintaining acceptable image clarity. Therefore it appears that the 3M anti-sparkle OCA is an excellent candidate to reduce sparkle in automotive display applications that use anti-glare structures on the first surface.

6. References

[1] https://upload.wikimedia.org/wikipedia/commons/b/bd/Lambert2.gif

[2] Sitter, B., Tebow, C., Zhang, Z., Anti-Glare Solutions for Automotive Displays, Society for Information Display 2016 Vehicle Displays and Interfaces Symposium Digest of Technical Papers.

[3] Hayden, B., et al, Anti-Glare Sparkle Optical Modeling & Prediction Method, Society for Information Display 2015 Vehicle Displays and Interfaces Symposium Digest of Technical Papers.

[4] Weindorf, P., Hayden, B., Automotive Display Visibility Considerations, Society for Information Display 2013 International Symposium Digest of Technical Papers.

[5] ASTM D 1003-07, Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics.