Anti-Glare Film Sparkle
Optical Modeling and Prediction Method
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Abstract: A refractive modeling and simulation method is proposed to understand the sparkle effect of anti-glare (AG) surface topological properties.

Keywords: Sparkle; Anti-Glare; Antiglare; AG

1. Introduction
Due to the increase in the complexity and expected functionality of electronics in vehicles there has been a trend to add touch panels to display systems. With the addition of a touch panel in front of a display, there is a greater interest in treating these materials to reduce the total reflection of the system and allow full functionality in strong sunlight conditions. Typically this can be done by adding either an anti-reflective (AR) film or an anti-glare (AG) film onto the top surface. Currently in the automotive industry the AR films are out of favor due to high cost, the amount of color shift in the reflected light and issues with the visibility of finger prints. More often, as depicted in Figure 1-1, AG films are utilized on the front surface to blur and scatter specularly reflected light sources so they are less objectionable to the user.

In addition, AG surfaces are less prone to finger prints. However AG surfaces may introduce some additional problems such as:

- Image clarity
- Sparkle

Image clarity determination methods based on knife edge test methods are outlined in reference [1] and are not discussed further. Figure 1-2 shows photographs of high sparkle and low sparkle screens whereas Figure 1-3 shows the imaging photometer measurement of high and low sparkle screens at the TFT pixel level.

The objective of this study is to describe modeling methods that may be utilized to understand the basic mechanisms that cause sparkle as shown in Figure 1-2 and Figure 1-3. These models may then be utilized to determine how to modify the AG structure to reduce the amount of sparkle.

Figure 1-2. High Sparkle (left) and Low Sparkle (right) Photographs

<table>
<thead>
<tr>
<th>AG Polarizer</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCA Glass</td>
<td></td>
</tr>
<tr>
<td>LR Film</td>
<td>Gasket</td>
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<tr>
<td>Display</td>
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Figure 1-1. Display and Touch Panel Configuration [2] in mm
2. Background / Objective

There have been several methods proposed to measure and predict the perceived sparkle as observed by the human eye. Most notably, Dr. Carl Evans proposed a method [2] relating the standard deviation of peak TFT pixel luminance measurements (Figure 2-1) with the luminance sensitivity of the eye and normalized operating display luminance as shown in Figure 2-2. The method developed by Dr. Evans is an extension of similar methods discussed in reference [3]. Another method to measure sparkle utilizes a laser as the light source as discussed in reference [4]. Other methods to measure sparkle are discussed in [5] with respect to image content.

Although this method shows excellent correlation between perceived sparkle and measured standard deviation of the pixelated luminance levels, the underlying cause of sparkle is only discussed in generalities when the “display pixel size becomes small enough to be comparable to the feature size in the AG film” [2].

In order to understand how to model an AG surface structure it is useful to first look at the surface topologies of a variety of AG films whose sparkle performance is detailed in Figure 2-2.

Determination of the AG surface structure turns out to be non-trivial due to the limited depth of field associated with high magnification optical microscopes, an example of which is shown in Figure 2-3.
Other methods may be utilized to understand the surface topology of AG films. One method that may be utilized to help understand the AG surface feature structure is through the use of the Wyko NT Series Optical Profiler which performs non-contact, 3D surface detail measurements using vertical scanning interferometry. Figure 2-4 shows several 3D analyses using the Wyko profiler.

**Figure 2-3.** 1000X Optical Microscope AG Film Surface

**Figure 2-4.** Wyko 3D Surface Analyses - High Sparkle (Left), Low Sparkle (Right)
In order to compare and understand how the surface feature dimensions contribute to sparkle, a high sparkle and a low sparkle sample were measured with the results shown in Figure 2-5 and Figure 2-6.

To better understand the mechanisms for sparkle causation, a refractive optical model was created and simulations were run using Synopsys LightTools 3D optical engineering and design software.

3. Description
At the heart of optical modeling AG sparkle is the creation of the surface structure. One method that may be utilized is the creation of standard object dimensions in LightTools as shown in Figure 3-1. Although different objects may be selected, the cone is often most similar to the structures on AG films generated with particles, but other structures including custom structures may be utilized.

Based on measuring the surface topologies of two different films at the ends of the sparkle spectrum per Figure 2-5 and Figure 2-6, the structure parameter configurations per Figure 3-2 (high sparkle) and Figure 3-3 (low sparkle) were constructed and analyzed. Notice that the cone top diameter was approximately zero for these simulations. The structure element pitch was randomized in Microsoft Excel® and over 100,000 cone elements were subsequently transferred to LightTools for optical simulation. For the high sparkle configuration, the pitch was randomized at $75 \pm 18.75 \mu m$ and for the low sparkle a pitch of $15 \pm 3.75 \mu m$ was utilized. Three cone angles ($2^\circ$, $5^\circ$, and $10^\circ$) were analyzed for each of the two element diameter configurations.
An example of a low sparkle AG model utilizing cone structures with 10° angles is shown in Figure 3-4. The LightTools software merges the random surface structures together with the base material to form a solid refractive object used in the optical simulation.

In addition to the AG lens, the TFT pitch structure must be modeled as shown in Figure 3-5. The TFT sub-pixel structure dimension and pitch were considered in the model for the actual TFT utilized in the sparkle measurements because the hypothesis is that as the AG feature size approaches the pixel pitch, more sparkle occurs.

The luminance profiles for the different surface structure sizes and different conic angles may be determined as shown in Figure 3-7. It is interesting that the result shows the semblance of sparkle for the larger structure size irrespective of conic angle whereas the smaller structure size shows very little sparkle. Figure 3-8 shows the associated luminance values across one row of TFT pixels. In addition the Fast Fourier Transform (FFT) spatial frequency domain components are shown with the reference contrast sensitivity function (CSF) of the human eye. When the inverse FFT is applied to the CSF filtered spatial frequency components, the resultant filtered line (red) is plotted in the spatial domain.

For reference, if the AG texture is removed from the lens surface, the results exhibit no sparkle as shown in Figure 3-9. The results obtained by optical simulations are similar to and mimic measured results such as shown in Figure 2-1.
Figure 3-7. Optical Simulation Luminance Profiles
Figure 3-8. Luminance and Spectral Comparisons
By overlaying the optical simulation luminance profile with the surface structure model, further insight may be gained as to the mechanism causing sparkle. As shown in Figure 3-10, when the 50μm diameter structure elements align within the TFT pixel, the light is scattered in the local structure element area and therefore does not appear as bright. Conversely, when there is not a structure element in the TFT pixel area, the light is not scattered and the TFT pixel area appears brighter. When smaller 10μm diameter structure elements are overlaid with the optical simulation luminance profile as shown in Figure 3-11, the TFT pixel luminance is much more uniform. This is due to an averaging effect of the scattered light from each of the smaller structure elements. Therefore it appears as if the size of the AG element relative to the sub-pixel size is the main deterministic factor for the amount of sparkle. It is expected that as the size of the AG structures becomes smaller, the amount of perceived sparkle will be reduced.
4. Conclusion
Refractive modeling techniques may be useful to predict display sparkle caused by AG surface structures. More modeling based on actual sample feature sizes and subsequent correlation to sparkle testing is required to fully validate the modeling technique. In the future, these techniques may be utilized to determine the AG structure sizes required to minimize perceived sparkle.

5. References
[6] S. Miyahara’s contributions to this paper occurred during his employment with Visteon Corporation, Hiroshima, Japan
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