ADVANCED MATERIALS TECHNOLOGIES

Supporting Information

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Lenticular-Lens-Based Colored Antiglare Dashboard Surfaces

Chengang Ji, Guodong Zhu, Cheng Zhang, Sunghyun Nam, Qiaochu Li, Liangping Xia, Weiguo Zhang, Debasish Banerjee, and Lingjie Jay Guo**

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1. Dependence of reflection from windshield on incident angles

The reflection at the air-windshield interface can be calculated by the Fresnel's law as plotted in **Figure S1**:

$$R_S = \left|\frac{n_1\cos\theta_i - n_2\cos\theta_t}{n_1\cos\theta_i + n_2\cos\theta_t}\right|^2, R_p = \left|\frac{n_1\cos\theta_t - n_2\cos\theta_i}{n_1\cos\theta_t + n_2\cos\theta_i}\right|^2.$$

Here, R_S and R_P are the reflections for the s- and p- polarized light, respectively; n_1 (n_2) is the refractive index of the incident (exiting) mediums; θ_i and θ_t are the incident and refracted angles, respectively. Since the ambient light can be regarded as the superposition of the p- and s- polarizations, the average reflection of those two components are plotted by the black solid lines in the figure. The obvious increase of the reflection at larger incident angles indicates that the rake angle is an important factor influencing the veiling glare analysis.

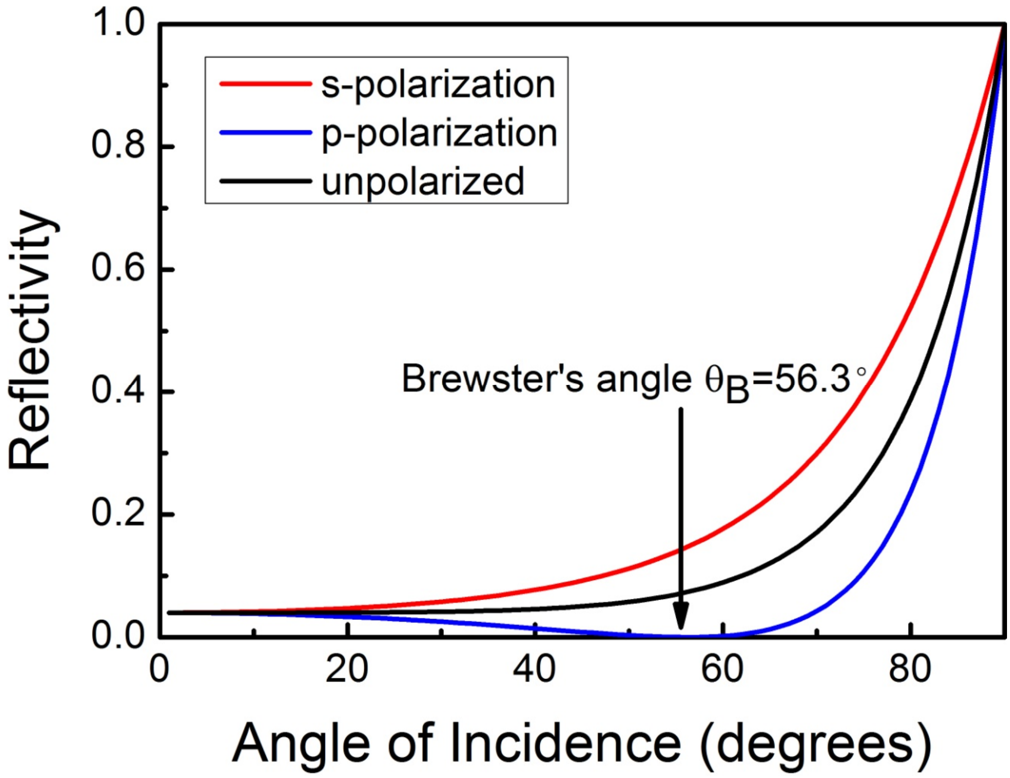

Figure S1. Reflectance of the air and windshield glass interface dependence on incident angles. The ambient light of daily driving environment can be regarded as unpolarized. The Brewster's angle for the p-polarization corresponds to an angle where reflectivity is zero. The refractive index of glass here is selected as 1.5 without dispersion.

2. Light propagation trace of the initial design

For the initial design with the lens thickness of $d = 71\mu m$, the light propagation trace is plotted in **Figure S2** for different incident angles up to $70°$. As analyzed in Section 2 of the main text, the out-coming light rays are refracted by both the single lens itself and the adjacent lens. Due to the aberrations from the cylindrical shape of the lens, the refracted light will fall into the veiling glare range at some incident angles.

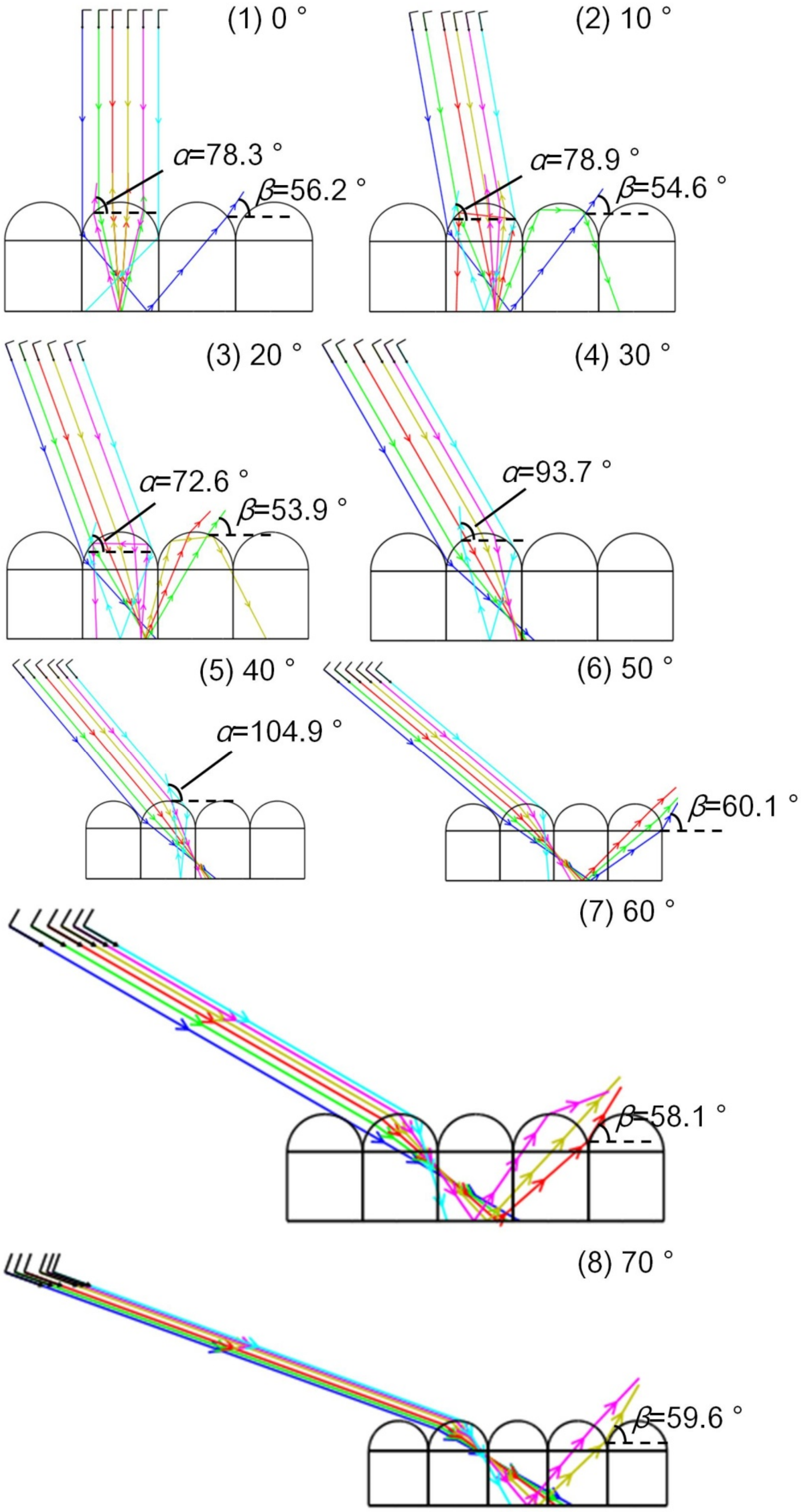

Figure S2. Trace of light rays from different incident angles of the initial designed lenticular lens (thickness $d = 71\mu m$). (1) – (8) correspond to incident angles from 0° to 70°, respectively.

3. Light propagation trace of the optimized design

The light propagation trace for the optimized structure is also investigated in **Figure S3** for different incident angles up to $70°$. By reducing the thickness of the lens to $d = 61 \mu m$, the aberrations are greatly reduced, and all refracted light at various incident angles are controlled out of the veiling glare range.

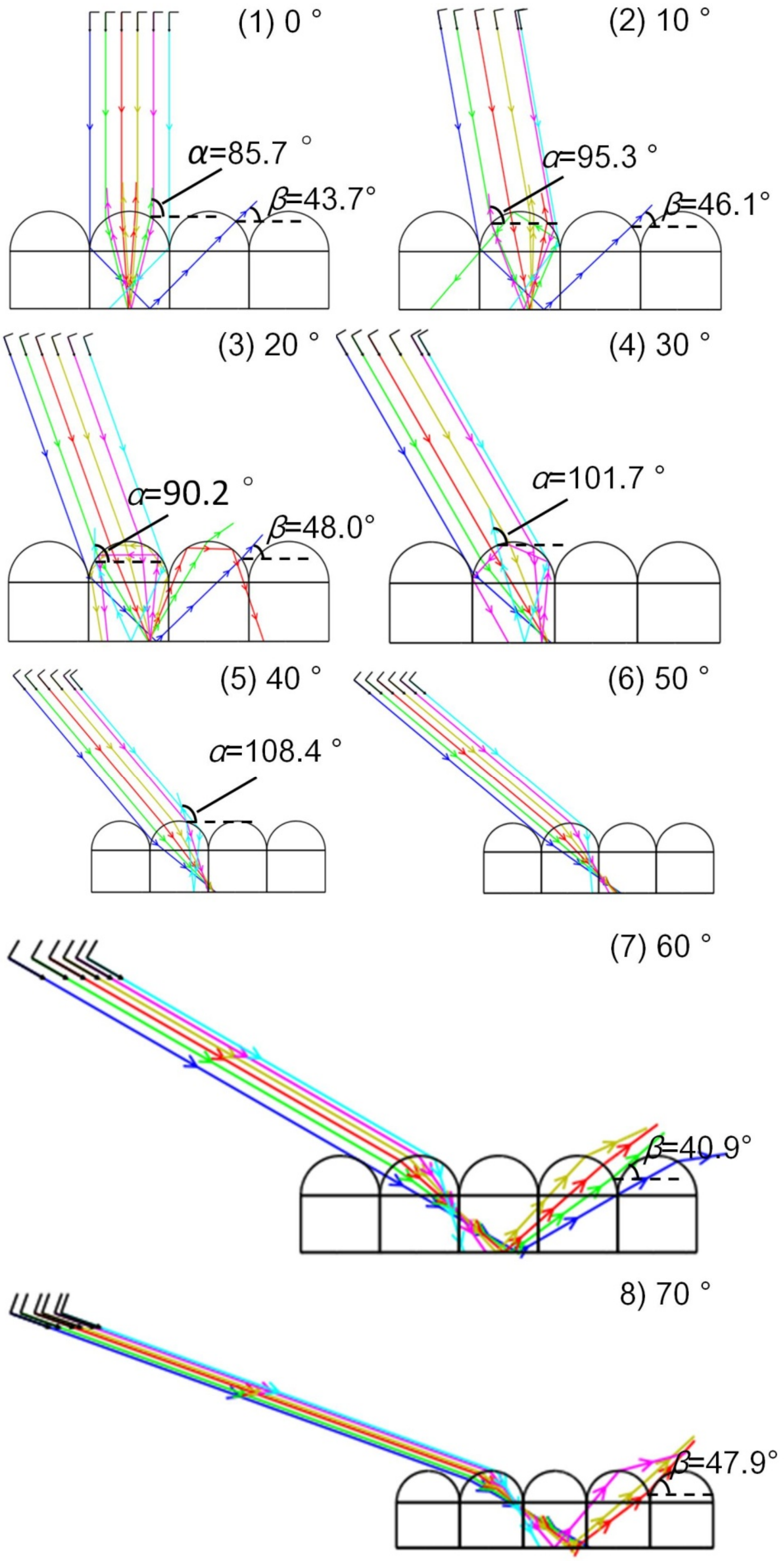

Figure S3. Trace of light rays from different incident angles of the optimized lenticular lens (thickness $d = 61\mu m$). (1) – (8) correspond to incident angles from $0°$ to $70°$, respectively.

4. Veiling glare angular range for side incident light

Veiling glare due to light rays coming from the vehicle side can also be removed by orientating suitable lenticular lens array with the lens length perpendicular to the incident light direction. Here, effective rake angle θ' refers to the angle between the windshield and dashboard in the incident plane and the satisfactory lens parameters can be obtained with Equation 4-6 based on the corresponding veiling glare angular range (defined by $\gamma_{\min} = 2\theta' + \varphi_2$ and $\gamma_{\max} = 2\theta' + \varphi_1$) assuming that the drivers' viewing angle φ remains as ±15°.

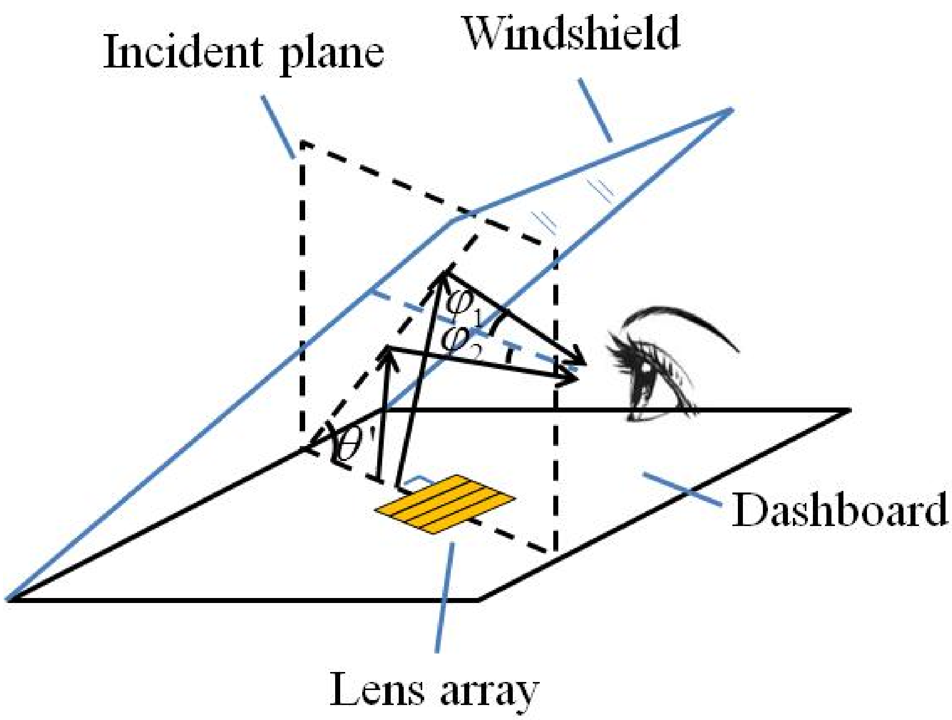

Figure S4. The schematic diagram for removing the veiling glare of light coming from the vehicle side. The drivers' viewing angle φ remains as ±15° and the lenses are well orientated so that the lens length is perpendicular to the incident light direction.

5. Diamond machining of the Ni mold

Figure S5 shows the process of the diamond machining for the Ni mold. $200\mu m$ Ni is firstly electroplated onto the Al plate. In order to control the overall thickness of the final imprinted lens, two $29\mu m$ steps are planed out at two edges with an ultra-precision five-axis machining system. Finally, the patterns for the lens array are created with the diamond tool.

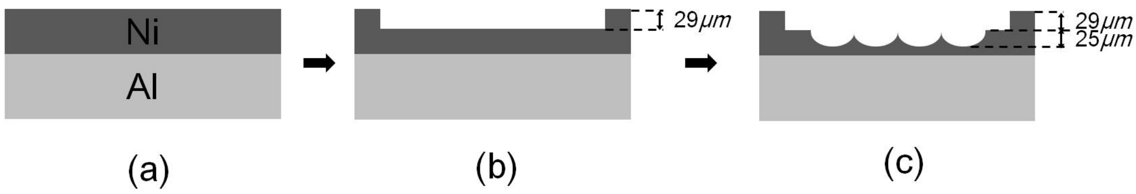

Figure S5. Preparation of the Ni mold with the precision five-axis planing machine.

6. Thermal imprinting and the alternating colored stripes

The imprinted lens, absorber/Au alternating stripe substrate by photolithography and the alignment between the lens and the substrate are shown in **Figure S6a-c**. The $7\mu m$ offset between the lens unit and the alternating stripes unit is achieved according the optimized design provided in Figure 4. **Figure S6d** shows even $100nm$ pitch mismatch between the lens array and the colored stripes will create the morié fringes. The right image is taken after putting the sample onto the windshield-dashboard setup as provided in Figure 6c. The projected colored stripes on the windshield are the morié fringes with a period of $2cm$. This also vindicates that the pitch mismatch between the lens and substrate of samples shown in Figure 6d are well controlled $<100nm$.

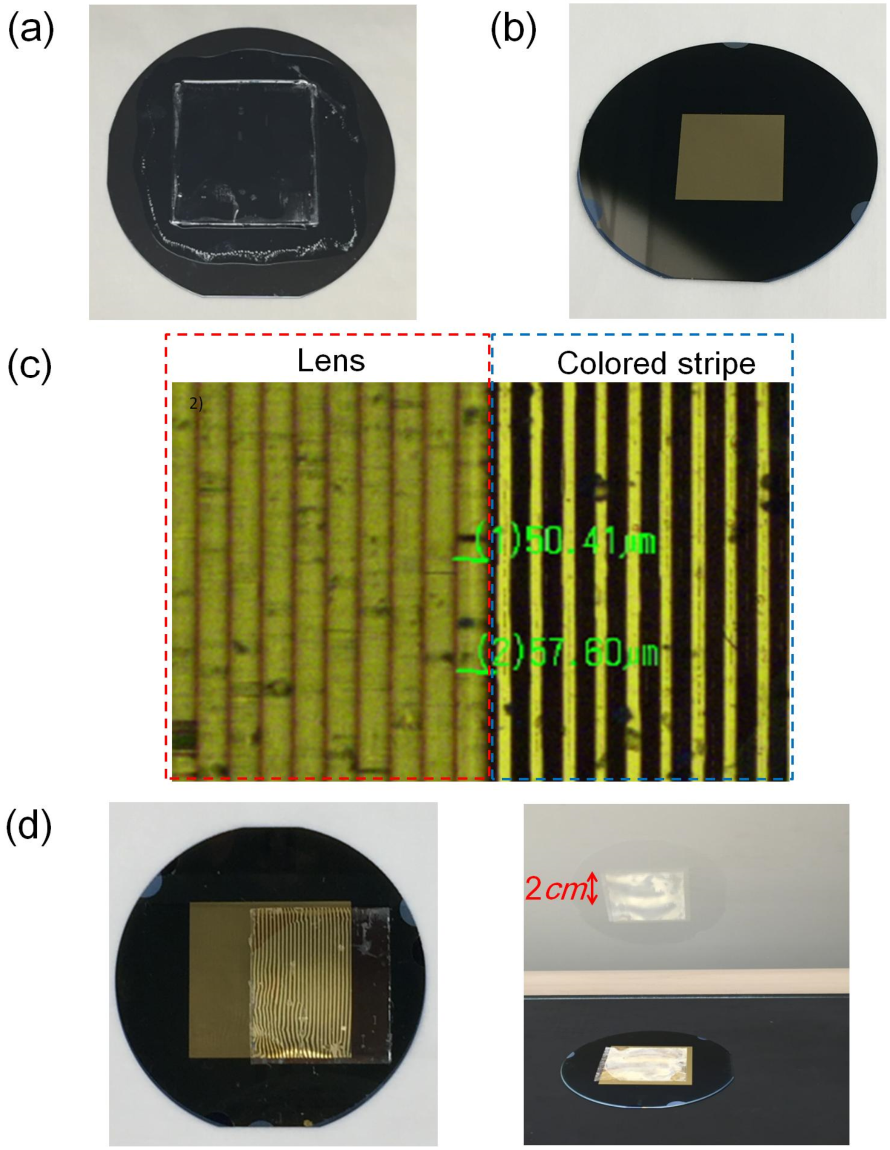

Figure S6. Alignment of the lenses and colored substrate. a)-b) Photos of the imprinted lenses and the alternating colored stripes, respectively. Both periods are 50*μm.* The yellow stripes (Au) has a width of 20*μm* and the width of the absorber stripe is 30*μm*. c) 7*μm* offset between a lens unit and an absorber/Au stripe unit is achieved under the microscope. d) The pitch mismatch between the lens and the substrate will cause the morié fringe. The left image shows the morié fringe of a period ~1.25*mm* corresponding to a 2*μm* pitch mismatch between the lens and the colored stripes. The right image shows the interference fringe with a period ~2*cm* corresponding to a 120*nm* pitch mismatch between the lens and the substrate.