

Plastic Window with View Control Function

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ABSTRACT

Plastic windows provided with a view control function that changes the level of transparency depending on the angle of view have been developed. In order to realize the view control function, special polymer films were selected which provide a clear view without ghost images and which possess a suitable relation between angle and opacity for each window. Taking the vehicle cabin environment into consideration, these special polymer films are sandwiched between hard-coated polycarbonate sheets, and the edges of the films are sealed with aluminum tape. In addition, a new film pressing process has been developed in order to help ensure stable quality. The use of the new windows in the next-generation fuel cell vehicle FCX Clarity has reconciled good rearward visibility for the driver with a practical trunk capacity, without affecting exterior design or vehicle standards.

1. Introduction

Attention is presently being focused on fuel cell vehicles as eco cars able to contribute to the resolution of environmental issues. The elements making up the powertrains of these vehicles, for example fuel cell stacks

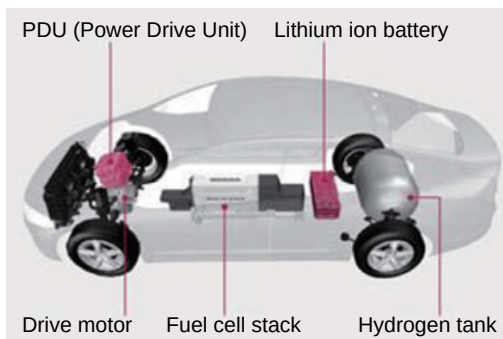


Fig. 1 FCX Clarity powertrain layout



Fig. 2 Rear view of FCX Clarity

and hydrogen tanks, are very different from those of conventional vehicles. Figure 1 shows the powertrain layout of the FCX Clarity, a next-generation fuel cell vehicle that went into production in June 2008. A reduction in size and optimum placement of the elements of the FCX Clarity powertrain have enabled the achievement of a high level of practicality while also realizing a sporty form with a low floor and low total height⁽¹⁾.

Figure 2 shows the rear form of the FCX Clarity. The hydrogen tank is positioned at the rear of the vehicle. The FCX Clarity is also fitted with an extra window in the upper section of the trunk lid, to increase rearward visibility for the driver. In order to realize a practical trunk capacity despite the restriction on trunk space due to the hydrogen tank, plastic windows with a view control function that changes the level of transparency depending on the angle of view (termed “view control windows” below) have been developed and used in combination with the glass extra window.

This paper will discuss the technological details of the developed view control windows.

2. Body Design around the Trunk

Figure 3 shows the FCX Clarity’s trunk space. With the positioning of the hydrogen tank behind the rear seat, the realization of a practical trunk capacity was the critical factor in the design of the body around the trunk. Increasing the overhang or the vehicle width at the rear

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Fig. 3 Trunk room of FCX Clarity

were considered as measures to secure trunk capacity, but the restrictions imposed by exterior design and vehicle standards prevented these measures from being implemented. The development project therefore examined the possibility of increasing the height of the trunk lid as a means of increasing the height of the trunk space. However, increasing the height of the trunk lid would reduce the vertical width of the rear window, thus reducing the driver's rearward field of vision. In order to increase trunk capacity without reducing the rearward field of vision, transparent plastic windows were positioned in the rear tray garnish and trunk lid lining (interior parts)(Fig. 4). (These windows will be referred to as the "rear tray window" and the "trunk lid window" below.) The use of these two plastic windows helped to ensure rearward visibility by enabling the driver to use extra windows in the body in addition to the rear window.

3. Visibility Design around the Trunk

The configuration shown in Fig. 4 provided good rearward visibility, but presented a new issue: when the vehicle was parked, people outside could look into the

trunk space from the side and the rear. It was desirable to control visibility from outside the vehicle in the interests of ensuring that the trunk space remained private. View control windows using films that changed in transparency depending on the angle of view (termed "view control films" below) were therefore developed. View control windows were employed for the two plastic windows in the rear of the FCX Clarity.

Figure 5 shows a plane view diagram explaining the relationship between the view control windows and the driver's field of vision. One aim established for the rear tray window and the trunk lid window was to help ensure visibility for the driver in the shaded areas, the rearview mirror visual area and the direct visual area. At the same time, it was desirable to restrict the visibility of the trunk space through the rear door windows to people standing at the sides of the vehicle. Taking an object positioned in the middle of the trunk space as an example, the areas in which visibility should be restricted would correspond to the two areas marked out by the broken lines in Fig. 5. The view control window used for the rear tray window was therefore one that provided a high level of transparency at the angle of the driver's line of sight, but a low level of transparency at the angle of the line of sight through the rear door windows.

Figure 6 shows a side view diagram explaining the relationship between the view control windows and the driver's field of vision. From the side view also, the aim was that the rear tray window and the trunk lid window would help ensure visibility for the driver in the shaded areas, the rearview mirror visual area and the direct visual area. At the same time, it was desirable here to restrict the visibility of the trunk space through the extra window for people standing behind the vehicle. Taking an object placed in the middle of the trunk space as an example, the area in which visibility should be restricted would correspond to the area marked out by the broken lines in

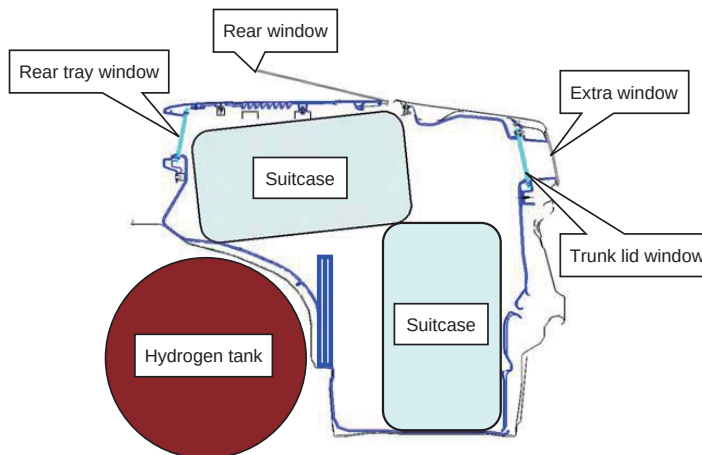
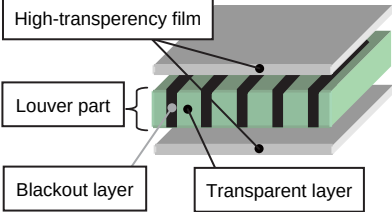
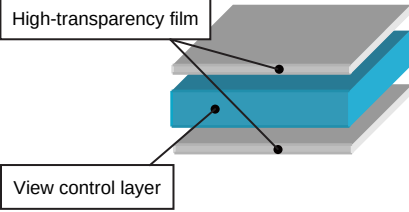


Fig. 4 Structure around trunk of FCX Clarity

Table 1 Setting angle and transparency of view control windows

Setting area	Setting angle		Setting transparency (haze ratio)
	Rear tray window	Trunk lid window	
Transparent area	From -10 to 10 deg.	From -10 to -30 deg.	20% Max.
Opaque area	From 30 to 50 deg., from -30 to -50 deg.	From 5 to 50 deg.	60% Min.

Table 2 Structures of view control films

	Louver structure film	Special polymer film
Structure		
Control factor	Light transmission	Haze ratio

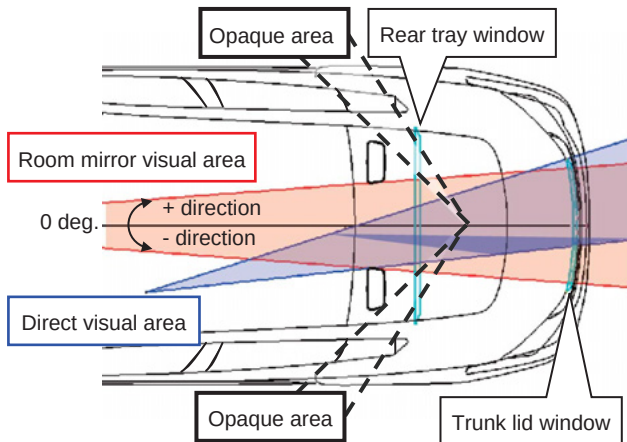


Fig. 5 Plane view of visual areas around rear tray window (for left-hand drive car)

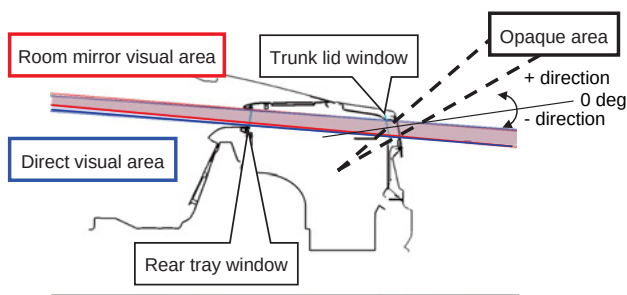


Fig. 6 Side view of visual areas around trunk lid window

Fig. 6. The view control window used for the trunk lid window was therefore one that provided a high level of transparency at the angle of the driver's line of sight, but a low level of transparency at the angle of the line of sight through the upper section of the extra window.

Table 1 shows the relationship between the angle of the view control windows and their transparency, as determined by verification based on the layout and measurements in an actual vehicle.

4. Selection of View Control Films

View control films can be roughly divided into two types based on their method of light control. Table 2 shows the structures of these two types of view control film.

Louver-structure films are made up of a louver section that functions to control light, and high-transparency films that protect the louver section. Blackout layers and transparent layers alternate in the louver section. The aperture ratio of the louver section changes depending on the angle of incidence of light, and the total light transmission of the film therefore changes. If the film is looked through at an angle at which its total light transmission is low, the view is dark and difficult to see. The mechanism described above enables the transparency of louver-structure films to change with the viewing angle⁽²⁾.

Special polymer films are made up of a view control layer that functions to control light, and high-transparency films that protect the view control layer. The view control layer is formed from alternating layers with differing indexes of refraction. This regular high-order structure

changes the level of scattering of light (the haze ratio) depending on the angle of incidence of the light. When the film is looked through at an angle at which its haze ratio is high, the view is cloudy and difficult to see. By this means, the transparency of special polymer films changes depending on the angle of view⁽³⁾.

Louver-structure films employ silicon rubber, a material with good optical properties, for the louver section, and these films therefore also offer the advantage of displaying good environmental resistance. However, the films also present a disadvantage in that interference between light entering at different apertures produces ghost images in the field of vision through the film. By contrast, special polymer films offer a clear field of vision through the film. Taking the ease of checking the view at the rear for the driver into consideration, special polymer films providing a clear field of vision were selected for use in the view control windows. Figure 7 shows the relationship between the angle of incidence of light and the haze ratio for the special polymer films used in the view control windows.

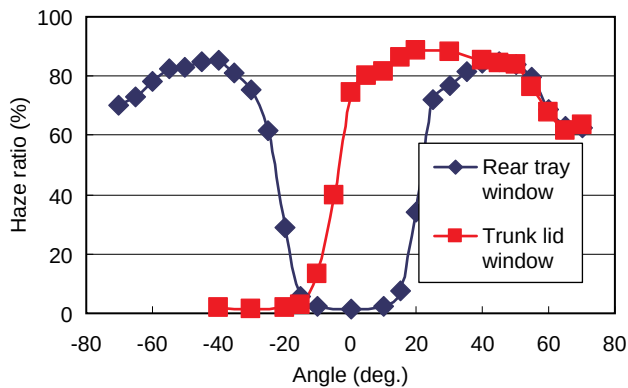


Fig. 7 Relation between angle and haze ratio for view control films

5. Configuration of View Control Windows

It was necessary to address two issues in employing special polymer films in a vehicle cabin environment.

The first of these was the fact that the films are prone to scratching. View control windows designed to enhance rear visibility for the driver would be required to display a high level of scratch resistance, but sample tests showed that the films were easily scratched.

The second issue was volatile substances. Sample tests that reproduced conditions in the cabin of a vehicle left out in the summer sun indicated the validity of concerns that volatile substances produced by the special polymer films would adhere to the surfaces of the view control windows and the inner surfaces of the glass windows, forming oil films and clouding the windows.

The view control window configuration shown in Fig. 8 was employed to address these two issues. The special polymer films to which an adhesive treatment has been applied are sandwiched between polycarbonate sheets, and the external surfaces of the sheets are coated with a polysiloxane hard coat with high abrasion resistance. In addition, the ends of the sheets are sealed with aluminum tape, which provides a good gas barrier. This configuration enabled the use of special polymer films in a vehicle cabin. Black paint has been applied around the external edges of the polycarbonate sheets, giving them a black ceramic appearance.

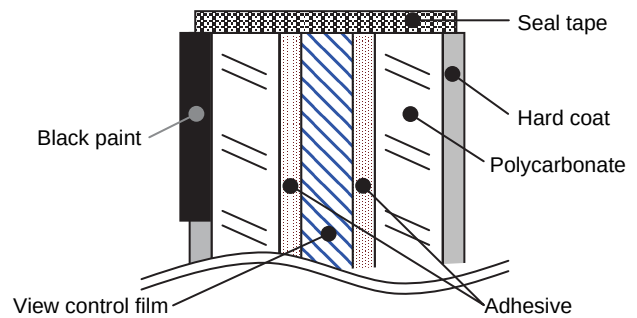


Fig. 8 Configuration of view control window

6. Production Process

Attention was also focused on the production process for the view control windows, in order to help ensure stable quality.

It was considered that if special polymer films were applied to untreated polycarbonate sheets, the water in the polycarbonate would volatilize in the heat, affecting visibility. The polycarbonate sheets are therefore heated and dried prior to application of the special polymer films.

In addition, given the comparatively large surface area of the parts, the view control films are pressed onto the polycarbonate under reduced pressure using a specially developed tool in order to keep air from becoming trapped under the films.

The development of this new pressing process for the view control films has helped to ensure stable initial and long-term quality in the view control windows.

7. Conclusion

Newly developed view control windows have been employed as the trunk lid windows and rear tray windows in the next-generation FCX Clarity fuel cell vehicle.

- (1) The use of special polymer films that display a low haze ratio at the angle of the driver's line of sight but a high haze ratio at the line of sight from the exterior of the vehicle has enabled a clear rearward field of vision to be

reconciled with the privacy of the trunk space.

- (2) View control windows able to be used in a vehicle cabin environment have been developed with optimal design of structures and materials.
- (3) Efforts to optimize the production process for the view control windows have helped to ensure stable quality.

The use of the view control windows has reconciled good rearward visibility for the driver with the realization of a practical trunk capacity, without affecting the exterior design of the vehicle or vehicle standards.

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