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Multifunctional Smart Glass technology

ZEISS

Holography for Automotive Applications

Head-up displays based on conventional optics, using lenses and mirrors, take up a large amount of installation space. This greatly limits their potential applications. The Multifunctional Smart Glass technology developed by Zeiss reduces the installation space required for these systems by more than a half. As a result, it allows augmented reality to be integrated as a safety feature into almost any car.

Head-up Displays (HUDs) are well established as human-machine interfaces in vehicle interiors that make life easier for drivers. Next-generation HUDs will do much more than simply relay a few pieces of driving-related information such as speed, remaining fuel, etc. Instead, they will support complete augmentation (the overlaying of digital content with the real environment) in the driver's field of vision. This will make an important contribution to driving safety. Zeiss has acquired more than four decades of experience with holographic solutions in the semiconductor, medical technology, and aerospace sector. The group is now offering this expertise to car makers.

Thanks to replication technology, holographic solutions will soon find their way into the automotive mass market. Zeiss has presented four application areas for its multifunctional smart glass technology [1], where holographic micro-optic technology can make driving safer, more interactive and more comfortable: transparent displays, floating switches, invisible cameras and holographic interior and exterior lighting.

TECHNOLOGY FROM SPACE

ESA and Nasa space missions have been relying on Zeiss components that use holographic process, such as optical gratings for spectrometers for gas analysis,

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FIGURE 1 The originals of every hologram type are produced in numerous clean room facilities and laboratories with specially developed high-tech equipment (© Zeiss)

for decades. The originals of every hologram type are produced in clean rooms, **FIGURE 1**, and laboratories with specially developed high-tech equipment in Jena (Germany). Through further processing, these holographic optical elements are turned into robust master elements suitable for industrial use. These can be copied by the customer in a fully automated replication process. This holography technology has now reached the point where its high-contrast, true-color and brilliant reproduction make it ideal for HUDs. This opens up access to entirely new markets.

One of these new markets relates to applications in cockpits of commercial aircraft, where this HUD technology will shortly be ready for series production. It offers decisive advantages, which have long been indispensable in aviation, as compared to conventional HUDs. These currently consist of a set of multiple complex lenses and mirrors, making them heavy and expensive. The augmented reality HUDs project a complete field of view as a virtual image and, thanks to micro-optics technology, allow the installation space to be reduced from around 40 to less than 10 l. At the same time, they only weigh around a tenth of conventional displays with equivalent performance in terms of image quality, field-of-view and image width.

FROM SINGLE ITEMS TO MASS PRODUCTION

With the use of multifunctional smart glass in automotive applications, the micro-optics technology cascade is entering the next stage. Until now, ultra-compact, holographic augmented reality HUDs could only be produced in small batches. With the replication technology, the fully automated duplication of a master hologram in large quantities is now possible for the first time. In addition,

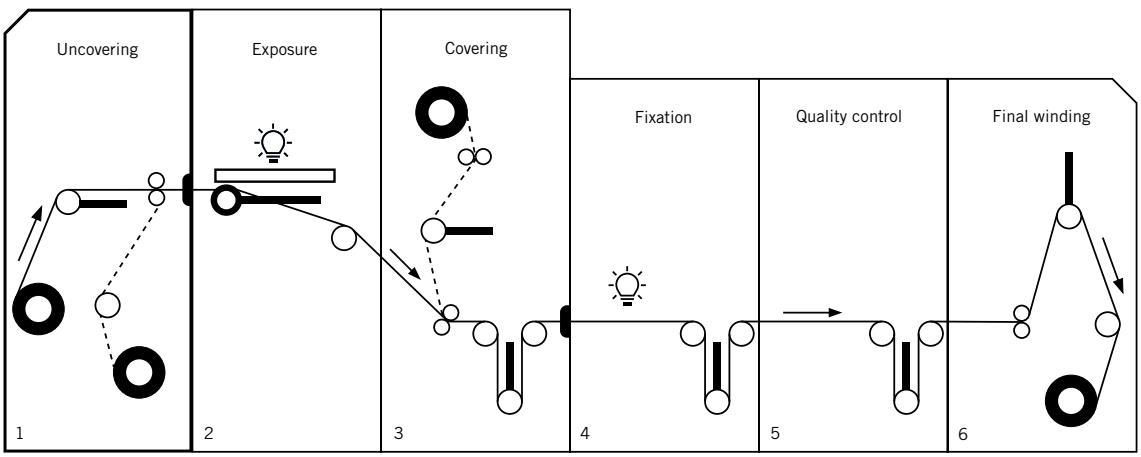

FIGURE 2 Schematic diagram of the replication machine (© Zeiss)

FIGURE 3 Warning symbols or emojis can be fully customized – even in rear and side windows; it is also conceivable to incorporate information on points of interest, restaurants or events; video content can be displayed (© Zeiss)

FIGURE 4 An example of holographic switches as an alternative to conventional 3-D control elements: They can be activated by voice commands or gesture control for example (© Zeiss)

each replicated copy can undergo complete quality control with no increase in cycle time.

The heart of the technology is a transparent layer on which ultra-high-precision optics are attached in the smallest of spaces. The layer, which is characterized by extremely high transparency and clarity, will enable vehicle manufacturers to use holographic technology where space, weight and cost limitations previously ruled it out.

In the replication and quality assurance facilities, **FIGURE 2**, the unexposed layer is delivered on a spooled backing film, which is inserted into module 1. After the light-sensitive layer is uncovered, it is transported to module 2, where the copy is produced through an optical transfer of all information. The copy is then protected by a transparent plastic laminate covering. It then passes through the fixation module 4, where it is exposed to light in selected wavelengths and doses in order to stop the chemical reactions and fix the optical functions. After fixation, each copied hologram undergoes quality control. The finished functionalized layer is wound up at the end of the line.

BENEFITS FOR SAFETY AND COMFORT

Augmented Reality HUDs have many advantages in cars: Drivers can concentrate on the road while receiving the information they need without distracting de-focusing. They are provided with selected information that they want or need within a field of vision of up to 25° and at an image distance of 10 m. This results in a significant safety advantage, especially compared to the ever widening displays, which harbor the risk of distracting drivers, **FIGURE 3**.

Compared to the classical HUD approach, using conventional mirror and lenses, the Zeiss Microoptics technology allows for a significant volume reduction by more than 50 % and maximum design flexibility, while delivering unprecedented image quality. This allows this comfort and safety feature to be implemented in almost any car.

Even without an augmented reality display, the projection technology offers a decisive safety advantage. The integrated, transparent and functionalized layer reduces the space requirements to less than 1 l. With the transparent, in-plane displays, this makes it possible to display all key information in any part of the windshield. This permits an entirely new vehicle cockpit design. Other advantages include simple functionality and greater comfort: for example, entertainment content can be projected in the front seat passenger's field of vision. The transparent layer with its display function is also suitable for side and rear windows.

NEW FREEDOM FOR INTERIOR DESIGNERS

With the steady trend towards simple, livable cockpits, where only safety-relevant operating elements are designed as mechanical controllers or buttons, customers and experts alike have become increasingly critical of the menu-driven, non-intuitive operation of comfort functions via displays. Holographic solutions can effectively support demands for design variety, individualization, functionalization and clean design, while at the same time guaranteeing maximum user-friendliness.

Multifunctional Smart Glass technology also opens up unprecedented design freedom. This technology permits a full redesign of the dashboard and vehicle interior – including individual configura-

FIGURE 5 The near-100% transparency of the layer permits the use of invisible cameras (© Zeiss)

tion and updates over the life cycle. It includes floating switches and invisible cameras and sensors – as described in the next section.

FLOATING SWITCHES

An example of the new design possibilities can be seen in floating switches, **FIGURE 4**. The heart of this technology is the unique transparent layer that is also used in HUDs and transparent in-plane displays. It allows 3D control elements to be displayed on demand as holographics – in other words, light projections – in the form of switches or controls on clean black-panel surfaces. Apart from the design of the control elements themselves, this offers designers new freedoms when creating interior spaces and surfaces. The floating switches are projected onto the surface only when they are needed and are activated by voice or gesture control. They can be positioned in any way the user wishes. Defined positions for physical switches can be almost completely dispensed with, while user feedback can be audio-visual or ultrasonic.

The floating switches are possible because the holographic layer can be applied to any transparent or non-transparent surface. Information can also be projected onto smooth, painted exterior surfaces. This makes autonomous driving applications conceivable – for example in Car2X communication – because content can be displayed clearly on windows or body components such as bumpers for other road users to see or read. This will make driving safer and more comfortable, customizable and interactive.

INVISIBLE CAMERAS AND SENSORS

Thanks to its almost perfect transparency of the holographic layer, cameras and sensors can be positioned behind it and intelligently concealed, **FIGURE 5**. That could be useful outside the vehicle for distance cruise systems or park pilots, for example, or for fatigue assistants or gesture controls in the interior. The transparency opens up new scope for the ideal positioning of cameras or sensors because the required installation space is no longer a factor. This not only permits a cleaner design, but also improves detection, which can now be implemented where it was previously not possible, such as in the driver's field of vision. This can greatly enhance the quality of gesture recognition, for example: The space in which a gesture can be made is several times larger than with conventional camera systems. This also improves the detection accuracy for various functions.

FUNCTION-ON-DEMAND

Another automotive trend is receiving new impetus thanks to innovations by Multifunctional Smart Glass technology, as it is completely software-controlled. As a result, it is also designed as a function-on-demand concept. All equipment and performance features of holographic solutions can be added later and transferred into the car over-the-air. This supports an increasingly important sales strategy for vehicle customization and an additional business model for OEMs.

SYSTEM TECHNOLOGY PROVIDER INSTEAD OF HARDWARE PRODUCER

The technology described has the potential to completely rethink parts and components in terms of design and function – components that Zeiss does not want to produce itself. Its core competence from aerospace is optical design, the creation of master holograms and – as a world first – their replication in industrial format as a transparent layer. The technology for the production of this layer can be made available to all manu-

The Zeiss microoptics enabling ecosystem
Capabilities required for microoptics mass fabrication

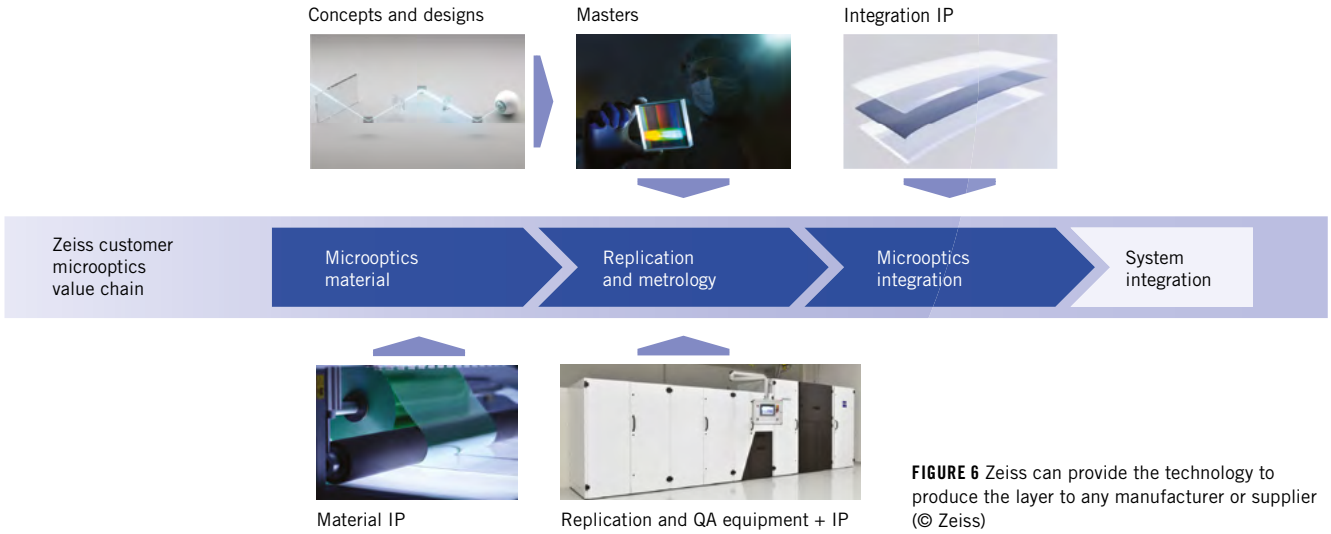

FIGURE 6 Zeiss can provide the technology to produce the layer to any manufacturer or supplier (© Zeiss)

facturers or suppliers who wish to add value to their products and incorporate functions now accessible – if at all – only to astronauts and pilots, **FIGURE 6**.

Due to the modular structure of the replication machines, built by Zeiss itself in Jena in collaboration with specialized partners, functions can be modified or added to meet customer requests. The machines can operate in standalone mode or be fully integrated into external production processes. National, international and company standards, quality processes and manufacturing execution system requirements are supported. In addition, Zeiss supports its customers with customized concept consulting from the first step to the finished hardware – another key building block toward firmly establishing the Multifunctional Smart Glass technology developed by Zeiss as a new, long-term standard in automotive series production.

REFERENCE

[1] Zeiss (ed.): Zeiss at the IAA Mobility for the first time. Online: https://www.zeiss.com/corporate/en/about-zeiss/present/newsroom/press-releases/2023/iaa-mobility.html, access: November 20, 2023

IMPRINT
Special Edition 2024 in cooperation with Carl Zeiss Jena GmbH, ZEISS Gruppe, Carl-Zeiss-Promenade 10, 07745 Jena; Springer Fachmedien Wiesbaden GmbH, Postfach 1546, 65173 Wiesbaden, Amtsgericht Wiesbaden, HRB 9754, USt-IdNr. DE81148419

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We offer the complete value chain from optical design and mastering to holographic replication systems for series production.

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