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Low Refractive Index Coating and Index Matched Adhesive Bonding for Lightguide Applications

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Abstract

Composite curved lightguides including prescription layers and/or protective layers are bonded together using index-matched adhesives. To obtain total internal reflection within the lightguide, a Chiolite layer is included on at least one side of the lightguide. For example, a Chiolite layer is included between the lightguide and an outer, world-facing protective layer, which is index matched to the lightguide. Due to the moisture susceptibility of the Chiolite, the adhesive coats the Chiolite layer to provide a moisture barrier.

Background

Curved lightguides can be used to make head mounted displays (HMDs) more socially acceptable because the curved lightguides may be formed into a standard eyeglasses or sunglasses shape. As such, the curved lightguides can be included in conventional glasses frames. However, to make sunglass versions, to protect the lightguide from scratches and moisture, or to add prescription capability, an outside layer on the world-facing side or prescription layer on the eye-facing side are required. To protect the world-facing side and/or to include the prescription capability, outside layers to the lightguide would need to be bonded to the lightguide by adhesive. For the lightguide to use total internal reflection (TIR) for propagating image light, the adhesive would need to have a low index of refraction. However, low index of refraction adhesives tend to have poor bonding strength and fail under physical and thermal stresses, which lead to delamination of the outside layers.

Description

An example HMD, as shown in Figure 1, includes two see-through eyepieces that provide image light to a user along with a view of the surrounding environment. The image light may be augmented reality data that provides information of one or more objects in the surrounding environment. Additionally, the image light provides other information to the user such as text messages, email messages, phone call information, etc. The HMD includes electronics and a display unit to project the image light to the user. The electronics are either coupled to a secondary electronics device that provides the data for generating the image light, or the electronics include wireless communication technology that allows for the receipt of the information via a wireless network, such as Wi-Fi or cellular.

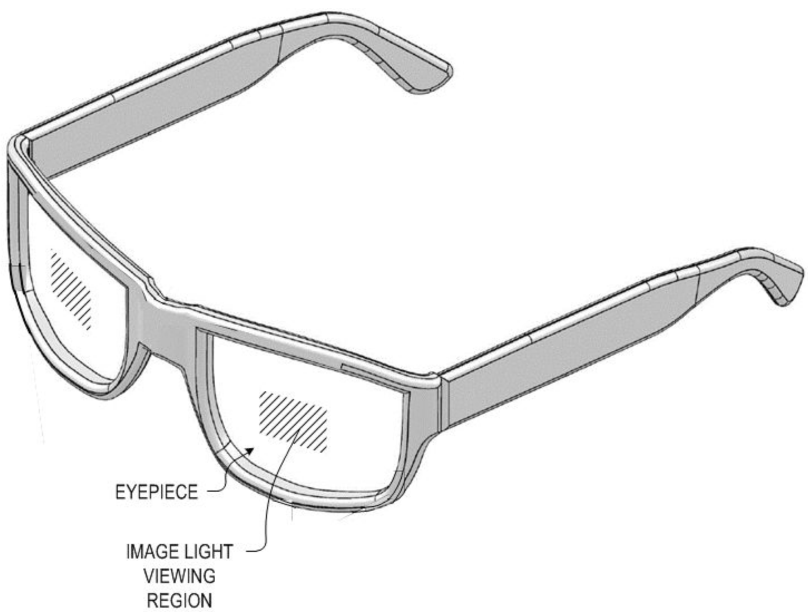

Fig. 1

Each eyepiece includes a lightguide that provides an optical pathway for the image light to propagate from the display unit to the image light viewing region, which is arranged to be aligned with the user's eye. The lightguide relies on TIR for propagating the image light from an input coupler to an output coupler, which redirects the light out of the HMD and toward the eye of the user in the image light viewing region. The eyepieces may additionally include vision correction lensing for the user and/or a world-facing protective layer and/or sunglass coatings. To bond prescription lenses and the world-facing protective layer to the lightguide, an adhesive bond material having an index of refraction matched to the lightguide, the outside layer, and the prescription layer may be used to bond the lightguide and layers into a composite eyepiece. However, to induce the TIR in the lightguide, a layer of Chiolite or other material (e.g., compounds of one or more of Aluminum (Al), Sodium (Na), or Fluorine (F)), which has a low index of refraction, is included in the composite structure on opposing sides of the lightguide.

An example eyepiece structure suited for an HMD is shown in Figure 2. The eyepiece structure includes a lightguide component and a see-through component. The see-through component is the outside layer discussed above. Image light from a display source enters the eyepiece at a side location incident on an input coupler. The input coupler, which may be a refractive or diffractive optic, redirects the image light along a path within the lightguide component toward the output coupler. While in the lightguide component, the image light may experience TIR due to index of refraction differences between the lightguide component and the Chiolite layer, and also due to the index of refraction of the lightguide and that of air. The Chiolite layer is between the see-through component and the lightguide component, and it provides a low index of refraction layer that induces the TIR due to the delta of the index of refraction between the Chiolite and the material forming the lightguide component. The index of refraction of the Chiolite ranges from 1.3 to 1.35 at a wavelength of 500 nm, and the material forming the lightguide has an index of refraction from 1.6 to 1.67. The lightguide component is formed from glass or optics-grade plastic. Additionally, the Chiolite is sensitive to moisture and must be protected to prevent damage. Fortunately, the adhesive bonding material coats the Chiolite and provides a moisture barrier.

A minimum thickness of the Chiolite is required to obtain the desired TIR for all visible wavelengths. Simulations show that the Chiolite should be at least 1.0 microns in thickness before nearly leakage-free TIR is obtained. The Chiolite can be deposited on either the eye-facing side of the see-through component or the world-facing side of the lightguide, and can be deposited using any known technique that provides the required minimum thickness. While Chiolite is transparent at such thicknesses, thicker layers may become visible and are desirably avoided. Minimizing the thickness is also desirable for reducing the stress in the coating and adjacent plastic for improved reliability.

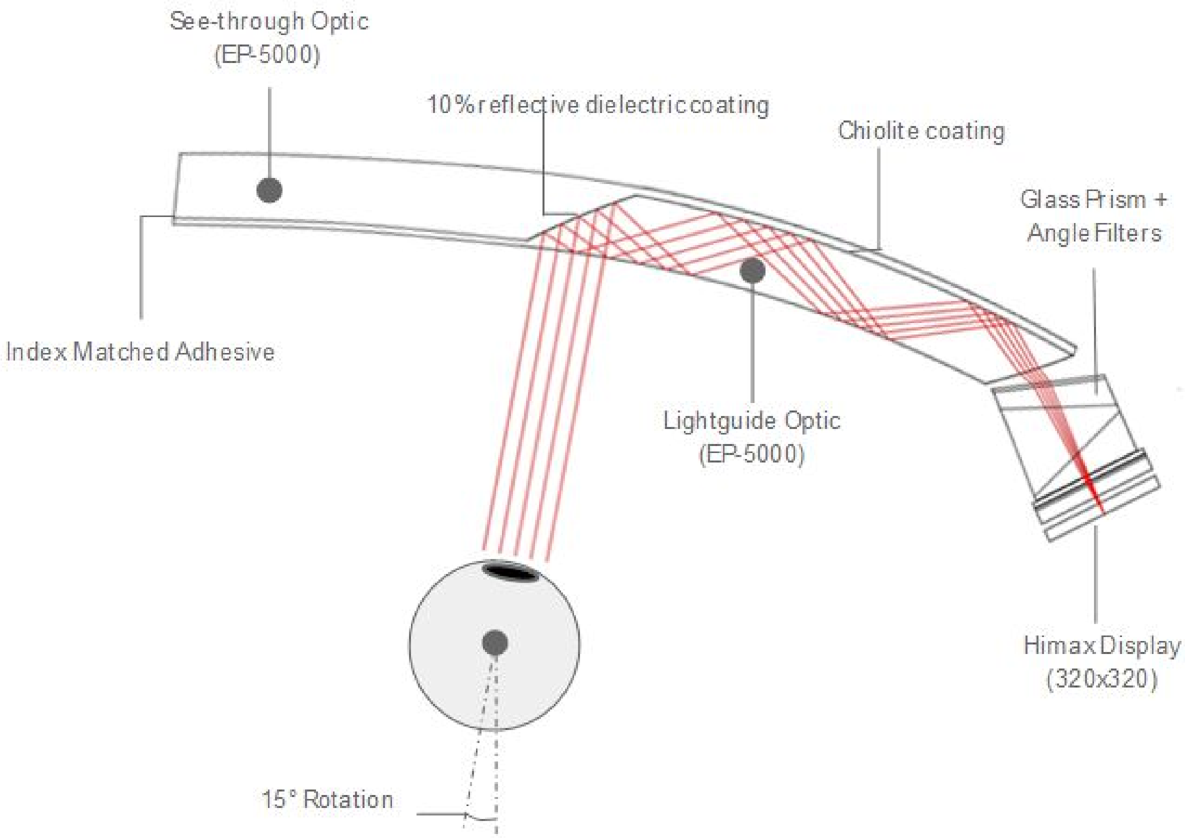

Fig. 2

The lightguide component has a thick portion and a thin portion, where the thick portion includes the input coupler and the output coupler. The thick portion also provides the optical path for the image light. The transition of the lightguide component from the thick portion to the thin portion is the output coupler. The output coupler provides a reflective or diffractive optic for redirecting the image light out of the eyepiece and toward a user's eye, and forms the image light viewing region as well. The thin portion of the lightguide component coincides and nests with a thick portion of the see-through component. Likewise, the thick portion of the lightguide component coincides and nests with a thin portion of the see-through component. Both the lightguide and see-through components of the eyepiece may extend across the entirety of the eyepiece so that no fillets or lines are formed within a user's field of view. Additionally, the see-through component is included so that that eyepiece is a constant thickness across the entire area of the eyepiece so not to introduce any aberrations, which also makes the eyepiece similar to conventional glasses eyepieces.

The Chiolite is not deposited on the point of transition of either the eye-facing side of the see-through component or the world-facing side of the lightguide component so that the point of transition is not visible due to the index of refraction mismatch. By preventing the Chiolite from being deposited in the transition points, the eyepieces will be free from visible lines even though the eyepieces are formed from and include multiple components and layers of varying thicknesses. Additionally, by filling in these transition points with index matched adhesive, they will be invisible.

Another example eyepiece structure suited for an HMD is shown in Figure 3. The eyepiece structure includes a lightguide component, a see-through component, and a prescription layer. The prescription layer has been formed to provide a desired vision correcting prescription, and the see-through component is the outside layer discussed above. The eyepiece structure of Figure 3 includes two Chiolite layers formed on opposing sides of the lightguide. Thus, while in the lightguide component, the image light experiences TIR due to index of refraction differences between the lightguide component and two opposing Chiolite layers. The Chiolote layers are between the see-through component and the lightguide component, and between the prescription layer and the lightguide component.

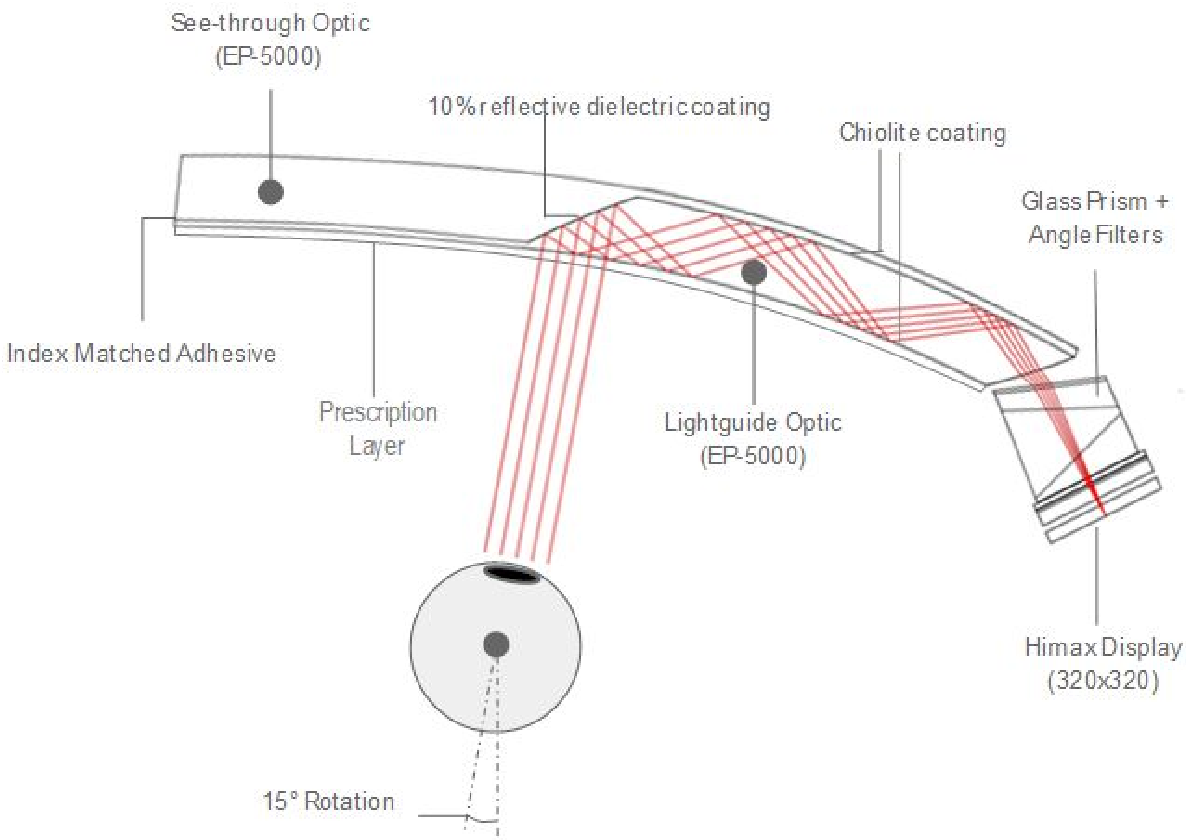

Fig. 3

The example eyepiece discussed above may be cut from a puck into a desired shape. An example puck is shown in Figure 4. The puck includes a see-through component, a lightguide component, and a Chiolite region as shown in Figure 2, but can additionally include a prescription layer as shown in Figure 3. Figure 4 shows that the Chiolite is deposited in a rectangular region that provides the TIR from the input coupler to the output coupler. With regards to Figures 2 and 3, the input coupler is located toward the perimeter of the puck and the output coupler is located towards the center of the puck. The output coupler is just outside of the

Chiolite region toward the center of the puck. With regards to Figure 2, the Chiolite region includes the Chiolite layer between the see-through component and the lightguide. With regards to Figure 3, the Chiolite region includes the Chiolite layer between the see-through component and the lightguide component, and also the Chiolite layer between the lightguide component and the prescription layer.

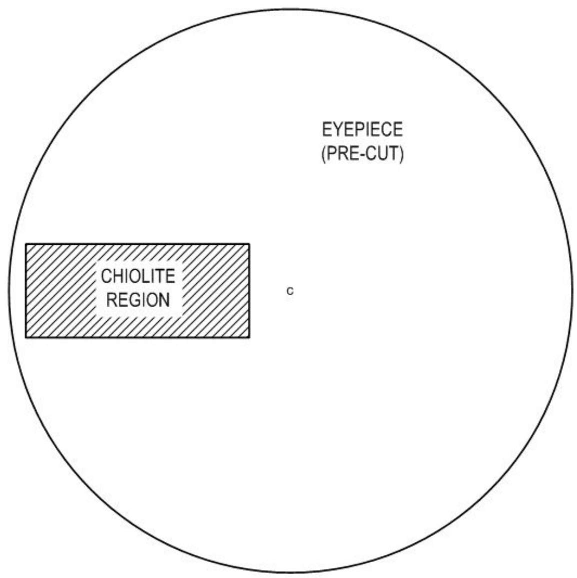

Fig. 4