Micro Heating Structures to Avoid Fogging Up of Glasses

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Abstract. Fogging up of glasses is a serious problem for every wearer of glasses. Entering a warm room from the colder outside causes fogging up of the glasses. Even after cleaning the glasses they keep fogging up consistently until the glass temperature adapts to room temperature. Heating the lens’ surface can avoid fogging up or remove already existing fog, as the rear window heating of a vehicle does. To adapt this principle the development of micro heating structures on the curved surface of a lens is required, which heat the whole surface uniformly still guarantying a sufficient transmission of light. In this paper a new and inexpensive photolithography process on convex surfaces is introduced. Therefore a commercially available polyester foil mask is thermoplastically deformed adapting to the shape of the lens to use it in photolithography process. A thin-film made from titanium and gold was deposited and patterned. An electrical circuit, containing a temperature sensor and a microcontroller, was designed to detect positive temperature changes as mentioned above and to control the heating of the glasses. Experiments demonstrated the capability of these ‘intelligent’ glasses to remove fog from the lens’ surface effectively.

Keywords
Photolithography, convex surface, heating structures, fogging up of glasses, thermoplastic deformation, foil mask.

1. Introduction

Every wearer of glasses knows especially in wintertime the fogging up of glasses when entering a warm room from the cold outside. By heating up a micro-structured resistor that is located directly on the surface of the lens fogging up can be avoided. For this purpose a thin metal layer has to be deposited onto the lens’ surface and then patterned by photolithography techniques and etching. While a thin metal layer can easily be deposited onto the convex lens’ surface the projection of a conventional planar mask onto a convex substrate does not provide the required quality for photolithography. This is due to the fact that the distance between the planar mask and the convex surface increases from the contact point in the center to the edges of the lens thus leading to an increasing scattering of light in the outer area (Fig. 1). As a result the reproduction of the mask is blurred on the edges of a convex substrate.

Fig. 1. Scheme of the coated lens and the planar foil mask. The red arrows illustrate the arising scattering issue due to increasing distance between foil mask and photosist.

In this paper a new photolithography procedure is presented that allows patterning of convex surfaces, utilizing the advantages of a conventional hard-contact exposure, which currently is only available for the patterning of planar substrates.

2. Methods

2.1 Adaption to wafer based processes

The difficulty of patterning convex substrates has already been the topic of several publications, which provide different solutions [1-7]. While each of these approaches provides the desired results, they are more complex and expensive than the conventional photolithography, often requiring a modified hardware setup or additional process steps such as molding techniques. For this reason it is more desirable to slightly modify the conventional hard-contact exposure to be able to utilize it on convex surfaces. Before performing photolithography it is required to apply photoresist onto the surface of the substrate. Since most clean room facilities are equipped with instruments that are optimized for planar wafers, the goal was to use existing wafer based processes and to adapt these if required. Therefore, the non-planar substrate was glued on a carrier wafer (Fig. 2) using photoresist, which was cured on a hotplate. This method makes it possible to use wafer processes even though a non-planar substrate is used.
However, it proved to be difficult to apply photoresist onto a convex surface due to the fact that the photoresist drains immediately after being dispensed on the convex surface even before starting the spincoating process. In order to avoid deviation of the resist due to gravity force [8], it turned out to be essential to keep the lens’ surface at room temperature since the viscosity of the resist is increasing with a lowering of temperature. The spincoating process and the following softbake should be started immediately after coating the non-planar surface to evaporate solvents and to achieve a hard film of photoresist.

### 2.2 Production of the curved foil mask

To realize the exposure process on the convex surface of the lens, we developed a new method for photolithography. For this purpose a mask, showing parallel lines, was adjusted to the curved substrate. To achieve this result polyester foil masks were used, which are characterized by low flexibility. Contrary to the standard procedure, these masks were not attached to a planar glass carrier. Instead they were clamped between two lenses and heated above the glass-transition temperature of polyester, thus allowing to adapt the foil to the uncoated curved surface (Fig. 3).

After cooling down to room temperature, the foil mask remained in the adapted shape, closely fitting to the convex surface of the lens and was removed from the mold. While Fig. 4 a) illustrates the contact issue between the untreated foil mask and the convex surface of the lens in the outer area, Fig. 4 b) shows the precisely fitting foil mask after thermoplastic deformation.

Hence the adapted foil mask can be used for photolithography on similar shaped lenses.

### 2.3 Fabrication of micro heating structures on a convex surface

Before performing photolithography, the foil mask can be easily readjusted to the surface coated with titanium and gold as a conductive material as well as photoresist. The reduced distance between mask and substrate consequently resolves the issue of blurred projection (Fig. 5 a)).

Fig. 5 b) shows a scheme of the remaining photoresist on the lens after performing the photolithography process. In Fig. 5 c) the resulting micro heating gold structure can be observed. In order to verify the quality and stability of the patterned photoresist and to form the micro heating structures, a standard chemical etching process in aqua regia and ammonium hydroxide was carried out.
3. Results

3.1 Analysis of the structure resolution

Fig. 6 shows a microscope image of the patterned photoresist on the lens' surface. Measurements revealed an achievable structure width of 20 µm, which corresponds to the indicated resolution of the utilized foil masks.

![Fig. 6. Microscope image of patterned photoresist on the lens' surface. Desired width: 30 µm.](image)

After wet etching and removing the photoresist, the structure has been analyzed under a microscope, revealing that the heating resistors on the lens' surface are continuous and possess straight edges (Fig. 7).

![Fig. 7. Comparison of the heating resistors in different regions of the lens: a) Left outer area b) Center c) Right outer area.](image)

Also the deviation of the heating resistors’ width in the outer area of the lens’ surface compared to the center is shown in Fig. 7, which is about 10% in this sample. This analysis indicates only slight deviations, which were due to three effects: a small remaining distance between the foil mask and the substrate, leading to a scattering of light during the photolithography process, slight deformation of the foil mask and an inhomogeneous metal etching process. While these deviations did not affect our results, in other cases, where a higher uniformity is required, compensated mask structures may solve this issue.

In addition to the optical analysis profilometer measurements were used to compare the distance between two heating resistors on the lens’ surface. These measurements revealed a deviation of less than 3% of the projected distance of 750 µm between two heating resistors in different regions of the convex surface. The final gold structure can be observed in Fig. 8.

![Fig. 8. Patterned gold structure on the lens after performing complete photolithography and etching process.](image)

For assembly purposes gold contact pads were established in the outer areas of the lens to contact the micro heating resistors to the electrical circuit.

3.2 Application: Intelligent glasses

The gold wires on the lens’ surface are used as micro heating structures. Positive temperature changes leading to fogging up of lenses (change from cold to warmer ambient temperature) can be detected by an electrical circuit using a microcontroller and a NTC thermistor possessing best sensitivity in the temperature range of this application. Once the temperature change is detected the gold wires are automatically biased leading to an increasing temperature of the lens’ surface.

![Fig. 9. Application of micro heating structures on glasses: intelligent glasses recognize positive temperature gradients to remove fog.](image)

After cooling down to -20 °C and subsequently exposing the glasses to room temperature (approximately 22 °C) a successful removal of the fog on the heated lens can be reached after 30 seconds at a surface temperature of 27 °C (Fig. 9, left lens). In comparison the unheated lens (Fig. 9, right lens) is still fogged reaching a temperature of -6 °C.
within 30 seconds after being exposed to room temperature. With this setup a quick removal of fog on a lens could be established using small gold wires as micro heating structures.

4. Conclusion

We established a photolithography method for convex surfaces, which is, compared to previous approaches, easy to perform and inexpensive. The adaption of the mask to the convex substrate was realized by heating up the foil mask leading to thermoplastic deformation. This new method makes it possible to fabricate micro heating structures on a curved surface. A geometric deviation of less than 10% of the nominal dimension was achieved. Based on this new photolithography process micro heating structures have been processed on a lens’ surface guarantying homogenous heating of the lens as well as high optical transparency. Using this technology intelligent glasses were developed being capable of heating the lens automatically thus keeping the surface free from fog.

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References


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