Laser based projection system for traffic collision prevention

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We propose a laser based visual communication lighting system to avoid traffic collision between road users. The lighting system consists of a holographic optical element, fabricated on photoresist using our lab-made optical maskless lithography setup which employs a Spatial Light Modulator. The structures are replicated on PMMA using a hot embossing system with an intermediate PDMS stamp.

1 Introduction

The use of coherent light sources in automotives provides new possibilities for a number of applications which includes high resolution lighting systems as well as for road safety, in particular, the risk of accidents caused by open car doors known as Dooring [1]. In order to avoid this phenomenon a visual communication system between the front vehicle and the following road user is essential. This can be achieved by using a laser based information projection system employing holographic optical elements (HOEs). As seen in Fig.1, the system consists of a laser source module and a holographic optical element to project the symbol on the road.

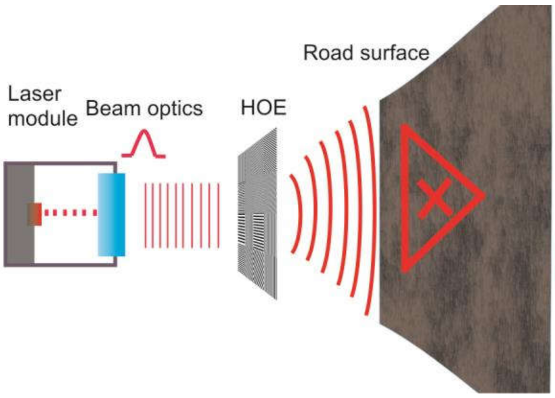

Fig. 1 Proposed design of the lighting system.

2 The design and fabrication

The surface profile of the optical element for the desired symbol or pattern projected for communication between the road users is computed using an iterative Fourier transform algorithm (IFTA). The algorithm is a modified version of the Gerchberg-Saxton algorithm and it uses a weighted technique in the image space and a gradient descent method in the HOE space for phase retrieval [2]. After computation of the surface profile of the optical element, it is physically realized using our lab-made maskless lithography optical setup as shown in Fig. 2. The optical setup employs a liquid crystal Spatial Light Modulator (SLM) having a resolution of 1920 x 1080 pixels and a pixel pitch of 8 µm, which is used to project the desired structure of the optical element onto the photoresist. We have used a UV LED having a wavelength of 405 nm in combination with the Köhler illumination system for homogenously illuminating the effective area of the SLM. Also, we have employed Shipley S1813 photoresist spin coated on the silicon substrate at a spin speed of 4000 rpm.

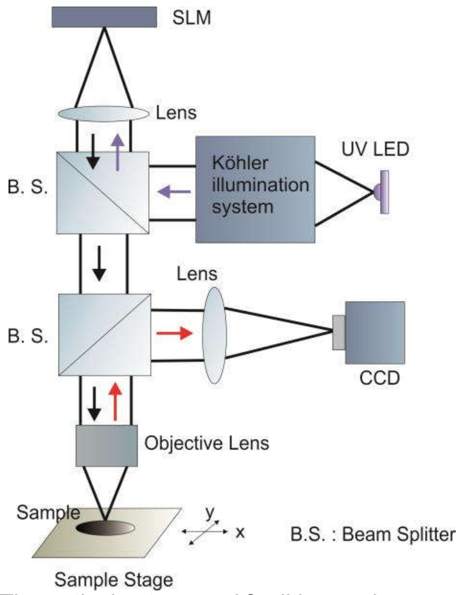

Fig. 2 *The optical setup used for lithography.*

As the photoresist is illuminated with the desired structure, it is then developed using MF26A developer for 60 to 90 s and dried using pressurized air. The structures are then used as a stamp for replication onto the polymer. The replication onto PMMA was realized by a hot embossing system where the polymer is heated to a temperature higher than its glass transition temperature and then pressed on the stamp containing the desired structures [3]. The stamp made of the photoresist

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is unstable at high thermal loads, so an intermediate stamp is required. We have used a polydimethyl siloxane (PDMS) stamp which is much more stable at high temperatures. PDMS is an elastomer and is widely used as a stamp material in hot embossing systems [3]. The structures on the photoresist are replicated on PDMS by a casting process. We have used ELASTOSIL® RT 607A/Ba with a ratio of 9:1 of the base and the curing agent, respectively, which is stirred for 3 min. A different ratio will either lead to much more flexible or more rigid stamps. The wafer containing the structures is placed in a tray and poured with the PDMS and left for two days at room temperature, see Fig. 3(a). The PDMS containing the negative replica of the structures is then separated from the wafer. The PDMS stamp is subsequently used as a master stamp for replication onto PMMA. The hot embossing system employed is HEX03 from Jenoptik. The parameters which influence the replication onto PMMA are the embossing temperature, the embossing force and the embossing time and the demolding temperature [3]. The PDMS stamp and the PMMA foil having a thickness of 500 µm are placed in the hot embossing system. The PDMS mold and PMMA are then heated to 140 °C which is above the glass transition temperature of PMMA. An embossing pressure of 7kPa is applied for 4 min. After cooling to a release temperature of 40 °C, the PDMS mold is removed from the PMMA manually, as shown in Fig. 3.

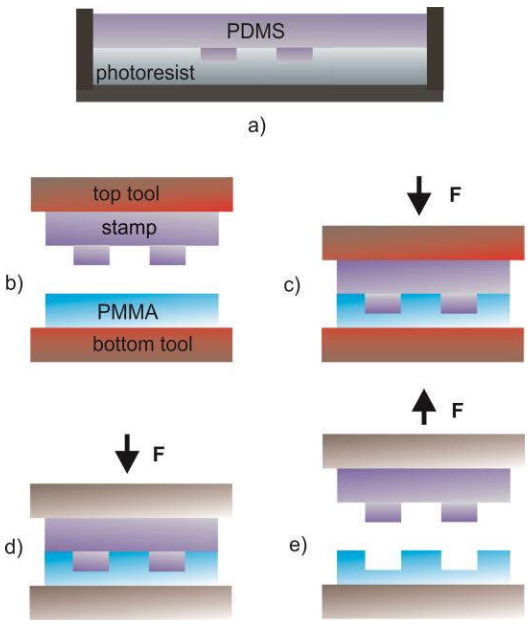

***Fig. 3** The replication process onto PMMA: (a) PDMS casting, (b) heating of the PMMA and the PDMS stamps, (c) embossing step, (d) cooling step, and (e) demolding step.*

The replication results of the desired holographic structures on PDMS and PMMA are shown in Fig. 4. The desired illumination pattern when illuminating the HOE with a He-Ne laser beam can be seen in Fig. 4(c). The illumination pattern shows a uniform intensity distribution and also an intense central spot which can be suppressed by fabricating multilevel holographic structures.

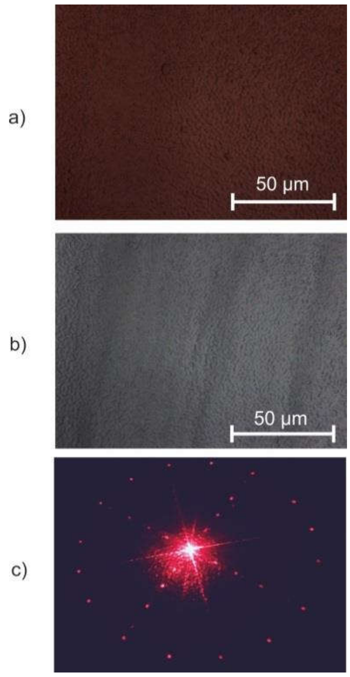

***Fig. 4** The replication of HOE structures (a) a negative copy on PDMS, (b) a replica on PMMA and, (c) the resulting intensity distribution upon laser illumination.*

3 Conclusion

We presented a cost effective process chain for fabrication of polymer based HOEs for automotive lighting. The HOE structure profile is computed using a modified Gerchberg Saxton algorithm and realized using a lab-made maskless lithography system. For replication onto PMMA, a hot embossing system is used with an intermediate PDMS stamp. The described process is cost effective and the proposed lighting system provides a laser based visual communication system between road users which might be useful to reduce the number of accidents in future.

References

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