Paper No: Optimization of thermoformed displays for smart contact lenses

C. Vanhaverbeke, A. Vásquez Quintero, L. Oorlynck, X. Shang and H. De Smet
Ghent University and imec, Belgium

Abstract
In this paper, the monitoring of the display cell gap of a spherical cap shaped liquid crystal display for smart contact lenses is described. This monitoring is important for further optimization of the display performance.

1. Introduction

Over the past few years technological progress was made towards the development of smart contact lenses. Application fields for these contact lenses include virtual reality viewing, biomedical control and vision correction. Within the field of vision correction, for both focal-length related conditions as for iris conditions, smart contact lens solutions are being investigated. For the latter two applications a liquid crystal display (LCD) is presented as the main component of the used smart contact lens and a guest-host LCD is currently being developed by us. The first prototypes were described in [1] and further improvements and alterations are ongoing [2].

2. Thermoformed display

The current design of the display cells consists of two flexible, transparent substrates of polyethylene terephthalate (PET) separated by cylindrical spacers to assure a controlled and uniform cell gap. In initial designs, the spacers were made out of SU-8 resist and the cells were sealed using a UV glue only at the border of the cell. Recently, we reported the use of a photosensitive adhesive (PA-S321) which has the advantage of serving both as a spacer structure and as a glue, thereby allowing the spacers to be attached to both PET substrates and thus providing a more uniform cell gap. In order to fit the curvature of the eye, the display is also thermoformed into a spherical cap. Also here a controlled and uniform cell gap remains important for proper behavior of the liquid crystals allowing a desired display functioning.

3. Cell gap monitoring

As this cell gap is an important parameter for the optimization of the display, it was monitored during the process flow described in [2] before and after bonding, after laser ablation and after thermoforming. To bond the cell, a 50 µm thick PET substrate is put on top of a 75 µm PET substrate which is patterned with 10 µm high PA-S321 spacers and this stack is heated and pressurized using a wafer substrate bonder. Before bonding, the height of the spacers is measured using scanning white light interferometry. After bonding, after laser ablation and after thermoforming, the cell gap is monitored using cavity interferometry.

It was observed that the bonding step leads to an increase in the radial direction and a decrease of the height of the cylindrical spacer, thus resulting in a reduced cell gap. Moreover, the larger the initial radius of the spacer, the smaller its radial increase and height decrease. From this observation a relationship was deduced between the initial spacer radius and the cell gap after bonding, as illustrated in Figure 1 with an example for a 10 µm spacer radius.

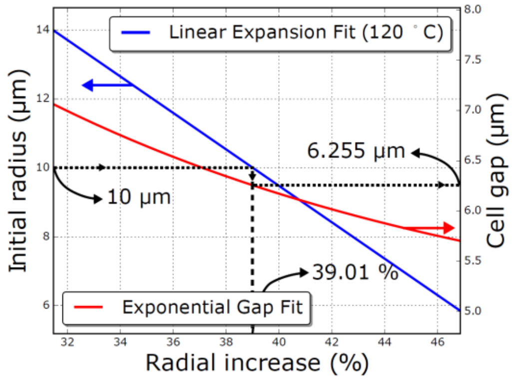

Figure 1: Initial spacer radius and resulting cell gap as a function of radial spacer increase during bonding

After bonding, the display cells are cut out using laser ablation for which no influence on the cell gap is observed. After thermoforming an increase in cell gap was measured, but no unambiguous relation could be deduced to predict the cell gap change. This outcome can be related to the dimensions of the thermoforming mold which is designed for a cell gap of 10 µm. However, spacer structures with an initial height of 10 µm, become smaller during bonding, leading to a non-optimal pressure distribution on the mold. Further investigation and optimization is needed here.

4. Acknowledgements

This research was funded by the Fonds Wetenschappelijk Onderzoek – Vlaanderen (FWO) through a PhD fellowship and by a Marie Sklodowska-Curie grant agreement No 661092.

5. References

[1] J. De Smet et al., "Progress toward a liquid crystal contact lens display", JSID, 21(9). pp. 399-406, 2013.

[2] C. Vanhaverbeke et al., "Microfabrication of a spherically curved liquid crystal display enabling the integration in a smart contact lens", Displays, 49. pp. 16-25, 2017.