Mechanical and optical design of flat lamps

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Mechanical and optical aspects are both considered to decide what kind of spacers (glass beads or Taglia® cross spacers) will fit flat lamps at best. It is shown that in flat lamps with gaps above 2 mm, optical aspects are critical, whereas mechanical aspects drive the choice for gaps under 2 mm.

Introduction

Spacing in Flat Lamps involves both optical and mechanical aspects. Glass spacers with high aspect ratio (Taglia®) are proposed by Saint-Gobain Display Glass for FED and Flat Lamps in the form of rib or pillar with rectangular or cross shape section[1].

Spacers are known to create unwanted shadows on the emissive side. However losses of emission related to the shapes of the spacers, have not been investigated yet. When thin glass substrate is considered (< 3 mm), it has been pointed out that the tensile stress on the outer side of the substrate is a critical parameter for the mechanical design [2,3]. However, the shape of the spacers is expected to impact on this stress. Moreover, indentation or damage induced by the spacer on the inner side of the substrate also depends on its shape. Possible indentation damage has to be taken into account, as it might become critical when the thermal stresses of the lamp are superposed to those due to the atmospheric pressure. These aspects are highlighted through the comparison between glass beads and Taglia® cross type spacers, for different gaps between the substrates.

Optical Considerations

One most important point for the visual aspect of a flat lamp is its luminous homogeneity. Most of the time diffusers are used to reach an acceptable level for this characteristic. However those ones reduce noticeably the luminous flux. If without diffusers, the luminous homogeneity were improved, the requirement on the contrast attenuation of the diffuser would be less stringent and thus the luminous flux could be increased.

With the help of a ray-tracing software, we have compared the simulated visual aspects of flat lamps with different gaps between glass panels equipped with glass beads or Taglia® spacers. The geometry of the spacers is given in Figure 1. The material used is a clear glass which is supposed to be absorbing for the UV radiation and transparent for the visible. Their surfaces are supposed to be characterized by a 30% Lambertian diffuse reflection. The only parameter to be modified is the gap H (which is also the spacer height).

The flat lamp is composed of two glass panels (Figure 2) with a homogeneous emission from the inside surface of the back panel. The emission in the UV range radiation is converted in visible light by phosphors on the inside surface of the top panel. The conversion of the UV radiation in visible light is not simulated. For visual aspects, the critical point is the absorption of the UV radiation by the spacers. We only put diffusing surfaces on one side of each panel.

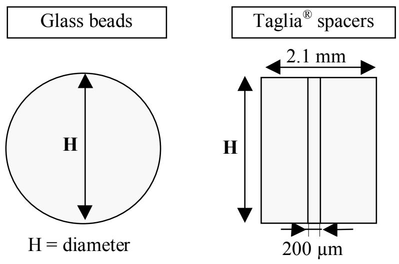


Figure 1: Geometry of the spacers

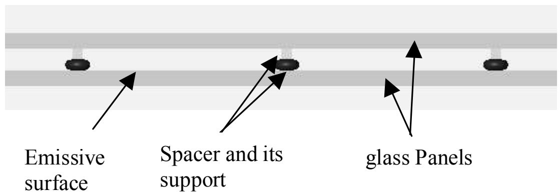


Figure 2: Geometry of the simulated lamp

Results: Spacers without Supports

In a first part the spacers have been designed in the lamp without supports. The results of the simulations are given in grey scale of luminance (Figure 3). On each image, 9 grey points of various intensities and shapes appear, corresponding to 9 spacers.

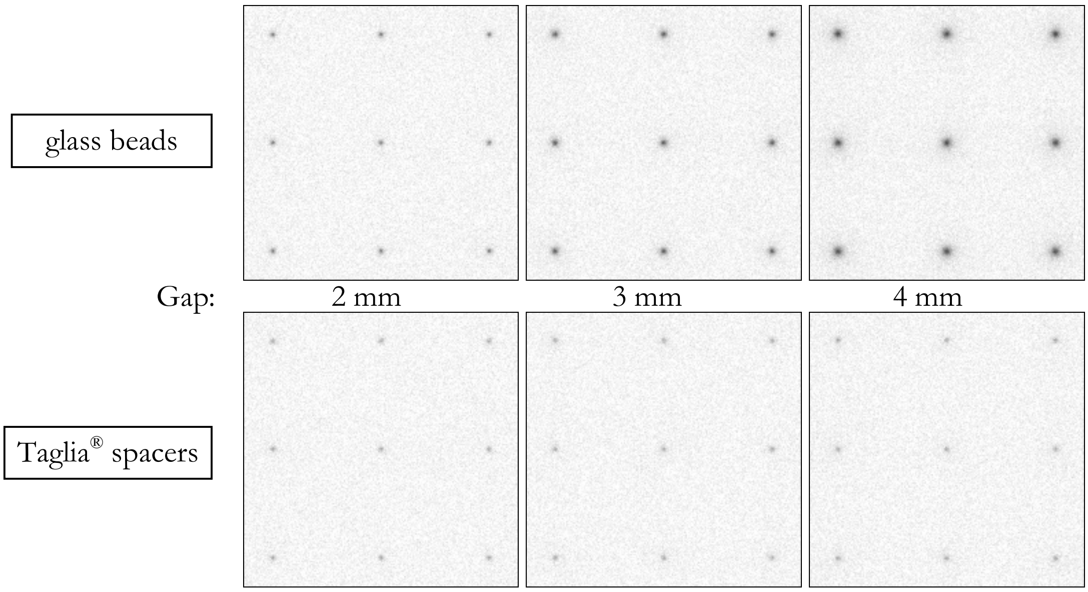
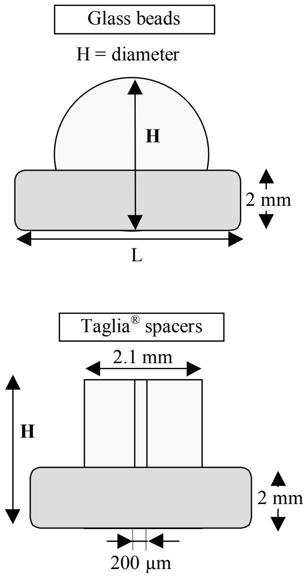


Figure 3: Simulations of a lamp with 9 diffusing spacers for different gaps

As expected, above 2 mm the difference in visual aspect between Taglia® spacers and glass beads increases in shape and intensity to the detriment of glass beads. In fact, due to the absorption of the UV radiation by the glass, the "key element" is the visible surface of the spacer seen from the top. As the gap H increases, the visible surface of the glass beads of diameter H also increases whereas the visible surface of Taglia® spacers does not.

Results: Spacers with Supports

In a second part, we have simulated the visual aspect of flat lamps in which supports are used to maintain the spacers. The support is a paste absorbing UV radiation and partly diffusing in reflection. It was designed as a ring of height 2 mm and diameter L around the spacer (Figure 4). We have simulated two different gaps H: 3 mm and 4 mm. For 3 mm, L is the same for the two different types of spacers: 4.8 mm. For 4 mm, L is 6 mm for the glass beads and 4.8 mm for the Taglia® spacers in order to be compatible with the diameter of the glass beads.



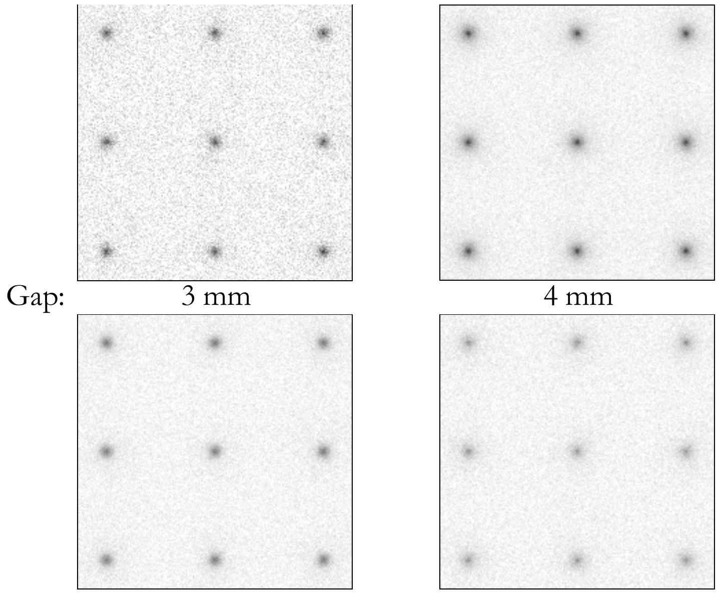


Figure 4: Design of the support

Figure 5: Simulations of a lamp with 9 diffusing spacers on a support for different gaps

As for the situation without support, when the gap increases, the homogeneity of the lamp is improved with Taglia® spacers, compared to the same lamp with glass beads (Figure 5) because the projected area remains the same unlike to the one with the glass beads.

Mechanical Considerations

We are now considering flat lamps having a gap lower than 2 mm. Vacuum inside the lamp generates mechanical issues that have to be overcome [2]. Among them, we concentrate first on the *tensile stress generated on the external side of the substrate*, which has a maximum σ_{max} just above the spacer. This side being exposed to ambient moisture and contacts that may generate flaws, this tension should not exceed some safety value. Then, the *damage generated at the spacer / substrate interface* is investigated.

Outside Stress

10 MPa was chosen for the limit that the outside stress should not exceed for a safely designed annealed glass subjected to permanent stress and exposed to ambient moisture. The problem is to find the maximum pitch λ allowable for a square arrays of spacers in order to keep with this limit. In order to investigate the effect of the type of spacer on the tensile stress induced at the outside surface of the substrates, a finite elements analysis (FEA) is performed. The ABAQUS software is used.

The lamp is supposed to be an infinite, regular square array of spacers. The unit cell of this lattice is a single spacer, centered on a substrate square having a width equal to the pitch λ. Thanks to symmetries, only this unit cell is simulated with boundary conditions of Figure 6. Dimensions are as follow: substrate thickness is 1.1 mm, gap between substrates is 1 mm or 2 mm, and Taglia® spacer geometry is that of Figure 1. This spacer may have a tilt angle with the square array due to its cross section: 0° and 45° angles are investigated. for the spacer / substrate interface, 2 different extreme contacting conditions are tested: perfect slippage and perfect bonding. Eventually, pressure differential is taken to be 0.9 atm, applied on the external side of the unit cell. A pitch λ=12 mm is chosen for the simulation. This value gives an outside stress of 10 MPa according to an analytical formula given in reference[4]. FEA results are shown in Figure 7.

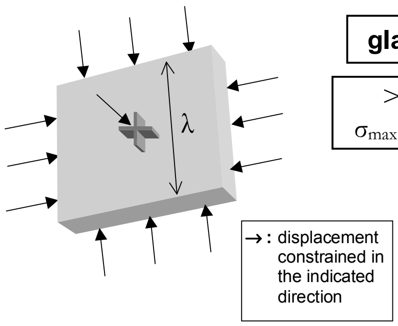


Figure 6: boundary conditions for simulation

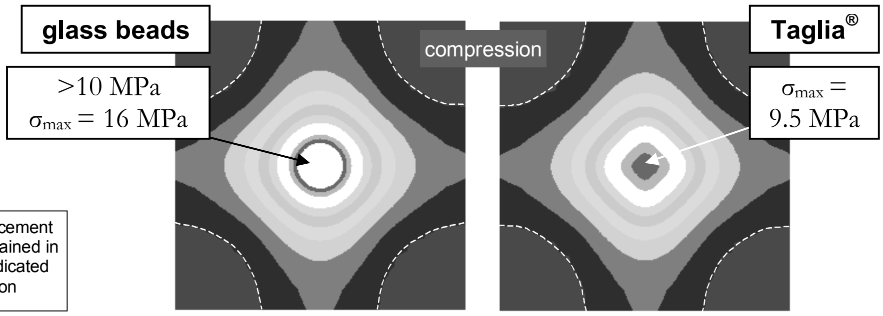


Figure 7: FEA results with λ=12 mm outside substrate is seen from above 1 MPa between each grayscale

For the tensile stress σ_{max} generated on the external side of the substrate, FEA shows that ❶ σ_{max} on the outside is lower with Taglia® than with beads (9.5 MPa versus 16 MPa). ❷ σ_{max} is the same for both gap values, even for the case of glass beads. This is consistent with results obtained for cylindrical pillars[4]. ❸ There is neither significant dependence of σ_{max} on the tilt angle of the Taglia® spacer, ❹ nor on the contacting conditions.

The safe pitch for beads is found to be λ=9 mm. Comparing with λ=12 mm, we see that using Taglia® saves about 44% of spacers. For a 42" lamp, it corresponds to approximately 6450 beads, whereas 3790 Taglia® would be enough.

Substrate Indentation

Because of Saint-Venant's principle, it is expected that the outside stress should not depend on the type of spacer for thicker substrates (> 2 mm). It is also expected that less spacers would be required, since the tensile stress experienced by the substrate would decrease. This means however an increase in the load per spacer, and hence a larger risk of damaging the substrate on the inner side. Therefore there is a concern about the indentation induced by the different kinds of spacers on the substrates.

The following experiment was made in order to get an insight into the damaging effect of the 2 kinds of spacers. In a first step (indentation), *a spacer is loaded on a 4 mm-thick glass sample*. The loading speed is constant. When the desired load is reached (100 N), the spacer is immediately unloaded. Quick loading (≈1 s for both Taglia® and beads) minimizes fatigue effect. Then, "*ring on 3 balls*" bending test is immediately performed on the glass sample (indented side under tensile stress) up to breakage (Figure 8). Loading speed is 20 MPa/s, to minimize fatigue effect as in step 1. This test is adapted for all spacer shapes, because induced stress is roughly isotropic and uniform under the ring, therefore any flaw is activated, whatever its orientation. Breakage stress is measured, and is used to evaluate the damage induced by the spacer.

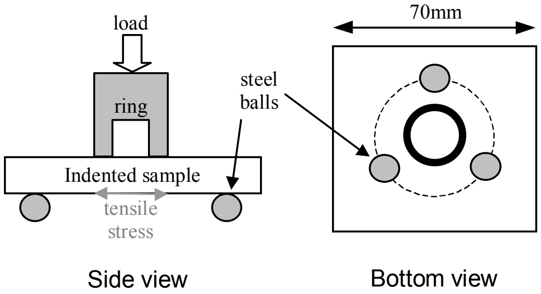


Figure 8: "*ring on 3 balls*" bending test

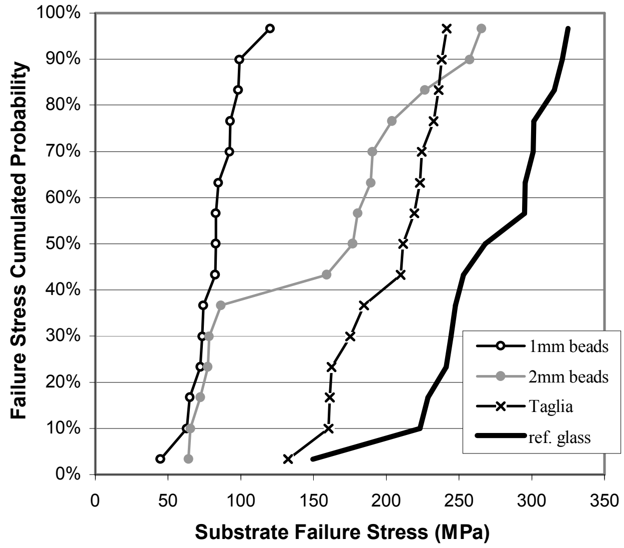


Figure 9: Weakening of 100 N-indented substrates

Broken samples were analyzed, and for all of them origin of failure was found to be where the spacer had been placed. Therefore results shown in Figure 9 only account for flaws induced by spacer indentation. Thus, the comparison between reference glass and indented samples shows evidence of *indentation weakening*. Moreover, the comparison between beads and Taglia® for a 100 N- indentation load, shows that the lowest failure stress is *70% smaller for beads than for Taglia®, whatever their diameter.*

Flaws created by beads are more serious than those created by Taglia®. Even if there is no moisture inside the lamp, and thus no fatigue of the indented substrate, these flaws might become critical when activated by the stress field due to the lamp thermal gradient.

Conclusions

It has been shown that for gaps higher than 2 mm, optical shadows created by glass beads are much more difficult to suppress with a diffuser than those created by Taglia®. For thin substrates (1.1 mm), the required number of beads is 44% higher than that of Taglia®, whatever the gap. High loads on spacers may be hazardous because of indentation damage, especially with beads.

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[1] Saint-Gobain Display Glass, private communication: Taglia® Technical Information Sheet

[2] R. Gy, D. Martin, D. Jousse, H. Nomizu in *IDW,* 1999, p. 931-933.

[3] B. Maag, R. Gy and D. Jousse, FPD Intelligence **8**, p. 76 (1999).

[4] R.E. Collins and A.C. Fischer-Cripps, Aust. J. Phys. **44**, p. 545-563 (1991).