CONSTRUCTION AND PHYSICAL PROCESSING OF ZEUS PANELS


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Abstract

The construction of a Zeus panel is discussed. This type of panel has a relatively simple self-aligned construction with a limited number of different components. Due to the low number of connections, rather robust connectors can be used. The complete physical processing cycle, very important for this type of panel, can be as short as 3 h which is shorter than the processing of a standard CRT.

Keywords: Zeus panel, display, construction, getter, channel plate, alignment.

1. Introduction

In many respects, the fabrication of the Zeus panel resembles that of the good old CRT, especially the fritting and processing procedures. However, many of the drawbacks, such as a two-step processing sequence and critical alignment of the electron gun parts of the CRT, have been eliminated in this new panel concept. In other papers in this issue the physical principles and technology aspects have been discussed extensively; in this paper the construction of the panel including alignment issues and the physical processing of the panel will be discussed.

2. Overall mechanical description of the panel

Basically the panel is a set of structured and metallized glass plates, including a channel structure, stacked together. This stack is fitted in an all-glass enclosure which also contains a phosphor screen, getter and cathode construction. In
Fig. 1 a schematic outline of the panel is given. A few of the indicated parts will be discussed in the following sections.

2.1. Enclosure

The enclosure is made of two borosilicate glass plates, of sufficient thickness to prevent breakage (see Sec. 3), forming the front and the back of the panel. On the inner side of the front plate the phosphor is deposited as described in another paper [1]. On the outer side of the back plate, a pump stem is attached for evacuation of the panel. The actual position of the stem is not critical but is chosen at the periphery of the panel. On the back plate a rim consisting of four glass strips is fritted using a solder glass with a proper melting point and expansion coefficient.

2.2. Channel plate

The channel plate, as depicted in Fig. 2, consists of a set of ducts through which the electrons are transported from the cathode section to the desired row in the panel. For a 28" panel with 24-fold multiplexing [2], the width of the channels is about 3 mm and the depth about 5 mm. The ducts should be as large as possible and therefore the walls as thin as possible to get a low transport voltage [3]. There are several methods for making these channels, e.g. sawing and grinding. However, due to the large amount of material to be removed in this way and limited number of walls an alternative makes sense: cut strips out of 0.4 mm glass and fix these at the appropriate distance on a glass plate using solder glass. This method yields a channel plate with smooth surfaces and straight walls, and therefore low minimum transport fields.

2.3. Stack of plates and alignment

As described in other papers, the main part of the Zeus panel is a stack of selection plates and a high-voltage spacer. These glass plates have to be aligned carefully with respect to each other and to the phosphor screen. The required tolerance is about 50 µm which is much less stringent than in other types of flat panels. The demand on the alignment was deduced from Monte-Carlo simulations and experiments. The alignment of the parts in matrix addressed panels is always a major issue. In Zeus panels there are more than two glass plates which have to be aligned which, in principle, makes the concept more critical. Fortunately, the requirements on alignment are only present for subsequent plates, without other absolute demands over the entire stack. Also, the technologies
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Fig. 1. Schematic outline of the Zeus panel.
used enable a construction in which the different glass plates are self-aligned. All glass plates are patterned by powder-blasting, as described in ref. [4], so we used this process step for making alignment marks together with the holes. In the masks used in the sandblasting process, alignment slits are etched during etching of the holes, resulting in a nearly perfect alignment between the holes and the slits. In the powder-blasting process these slits are converted into grooves in the glass which are used for mechanical alignment of the glass plates. In Fig. 3 the configuration of two aligned plates, using a small-diameter metal tube, is shown. This type of alignment is not only used for the structured glass plates but also for aligning of the set of plates with respect to the phosphor pattern and in the lithographic steps used for making the metal tracks and the phosphor pattern. The cathode wire is aligned in the same manner with respect to the $g_1$ and $g_2$ holes.

We have found that it is possible to achieve a close to perfect alignment

Fig. 2. Channel plate made by fixing strips of glass at the appropriate distance as indicated for a 28" panel.
between the different patterns and parts without any additional alignment tool by using the process steps which are used for making the parts. It has been found that in this way an alignment within 10 μm can easily be obtained, which is much better than the specification found as a result of Monte-Carlo simulations [5].

2.4. Connections

A major complication of most matrix displays is the number of connections. As explained in ref. [6], the Zeus panel has a greatly reduced number of connections. Due to this number which is small given the size of the panel, the pitch of the connection is much larger than for other types of flat panels such as LCD or PDP. This opens the way to use other, more reliable, connection methods.

As shown in Fig. 4, the stack of glass plates is built up symmetrically. All the plates have the same size but are alternately shifted in the vertical plane in the
horizontal direction by a few millimetres. The connections to the individual glass plates have to be made at the right or left side of the plates. This makes it possible to contact all the plates before mounting and aligning.

It is preferable to have the critical connections inside the panel because of lifetime demands. We have chosen spring-type connectors inside the vacuum envelope which slide over the metal tracks on the glass plates as depicted in Fig. 5. Feed-throughs of a suitable thin metal, directly through the frit seal, are used to make the connections to the electronics. There are two conflicting demands on the metal to be used for the connections. First, it must keep a good spring constant after baking at 450°C and secondly, the expansion coefficient has to be almost equal to that of the glass-frit used. This is the reason for making the feedthroughs from two pieces of metal as drawn in Fig. 5. One part has a good spring capability and the expansion coefficient of the other part fits the expansion coefficient of the glass. The parts are joined by laser-welding.

Due to the limited number of connections, the distance between the wires is large enough to keep the maximum field strength, without additional precautions, below 150 V/mm which is a safe value.

2.5. Triode construction

The main problem in the triode section of a Zeus display [7] is the proper alignment of the wire cathode segments with respect to the grids. An accuracy of about 10 μm in the cathode-to-g1 distance of about 300 μm is required. As discussed in ref. [7], the triode grids consist of glass plates with sandblasted holes and metallization. The glass plates can be separate or part of the
selection plates closest to the channel plate. In the latter approach, as shown in Fig. 1, the correct positioning of the triodes with respect to the channels is automatically achieved.

The accurate positioning of the wire cathodes is achieved by leading the wires through slits in a glass carrier (Fig. 6). The coarse geometry of the body is defined by sandblasting; the fine slits, 50 \( \mu \text{m} \) wide, 300 \( \mu \text{m} \) deep, are ground. During grinding the depth of the slits is very accurately controlled with respect to the carrier surface. In the final assembly, this surface is pressed against the \( g_1 \) grid, which guarantees the desired cathode-to-\( g_1 \) distance. The alignment in the other two directions is less critical, and is realized with the groove-and-tube method mentioned above and shown in Fig. 3.

The glass cathode carrier incorporates other functionalities as well. The wire cathodes are attached to metal springs which can accommodate the change of wire length between room temperature and operating temperature as shown in Fig. 7. The springs in turn are attached to the glass carrier. The carrier itself also serves to shield the cathodes from the electric fields originating from the selection plates. To this end the carrier is coated with a conductor on the inside (Fig. 8), of course preventing electrical short circuits. In addition, the vibration damping elements (not shown, see ref. [7]) are incorporated in the carrier.
3. Assembling method and internal vacuum support

The main advantage of this flat-CRT concept, making it more promising than other thin CRT panel design suggestions, is the internal vacuum support. Due to this built-in strength, the enclosure can be made of thin glass. This makes the panel relatively cheap and low in weight. The complete internal vacuum support is achieved during the fritting procedure. In Fig. 9 the implementation of the vacuum support is sketched in three steps. Before processing, the stack of glass plates is mounted on the screen which lies upside down on a flat hotplate (a). The back of the panel, including the rim and the frit, is put on top of it (b). A second hotplate is mounted to heat the back of the panel. The problem is that the frit shrinks about 30% during the frit cycle. This means that the total package is not internally supported before heating up. Above 300°C, when the solder glass has melted, the back of the panel and the upper hotplate sink upon the stack of glass plates; the weight of the hotplate presses the panel together (c). Only when the panel is properly pressed together is it possible to evacuate it without breaking the front or back plate of the panel, provided of course the whole support structure is in place.

In any construction of this kind, there are areas lacking vacuum support. It can easily be calculated that the maximum allowable unsupported span is about 2 to 3 cm for 2 mm glass thickness. Surrounding the stack of glass plates there is an unsupported area bridging about 1 cm for making connections between the glass plates and the feedthroughs, which is within the allowable margin.

4. Physical processing

Zeus panels work thanks to secondary emission electron processes, hence special attention has to be paid to the surface properties of the inner side of
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Fig. 9. The three process steps made to achieve a full support against outside pressure.

a) Stack of glass plates

b) b)

Hot plate

c) Unsupported area

the panel after the physical processing. The walls of the channels and the selection holes should have the pristine physical properties of the coatings deposited on them. This means that all ubiquitous carbon compounds have to be removed during fritting and pumping. This is achieved by burning the hydrocarbons at high temperature in air and removing the CO, CO$_2$ and H$_2$O by thermal desorption and pumping. Longer processing time results in cleaner surfaces. But, on the other hand, this time should be kept as short as possible to prevent damage to the cathode wires and to reduce the cost of this production step. The processing cycle used is shown in Fig. 10 and is a good compromise between the conflicting demands. During the first part of the cycle the panel is heated up to 450°C in air, and in this stage all the carbon compounds are burned away. At temperatures above 300°C the vitreous frit melts and in this temperature range the panel is pressed together as discussed in Sec. 3. After cooling down to 300°C the panel is evacuated. After cooling to
Fig. 10. Optimized process cycle of Zeus panel: in the first step the frit melts and the panel is pressed together; in the second step the panel is cooled and pumped.

room temperature the pressure is usually about $10^{-6}$ Pa. Then the cathode is activated, the barium getter is evaporated and the panel is sealed off.

The complete physical processing cycle takes about 3 h.

5. The getter

The maximum allowable total pressure inside the panel has to be below about $10^{-1}$ Pa, otherwise the electron transport is seriously hindered by collisions with gas molecules. However, other aspects demand a lower pressure and in practice $10^{-6}$ Pa is considered to be the pressure aimed at. Because of the degassing of the glass and the coatings after sealing-off, as a result of thermal desorption and electron-stimulated desorption (ESD) processes, continuous pumping is necessary to keep the internal surfaces as clean as possible. For this purpose a barium getter is incorporated in the panel. In Zeus panels the ESD will be largest after switching on for the first time. To protect the cathodes from an undesirable gas load, a high initial pumping speed is preferred. Fortunately, the pumping speed of a fresh barium mirror is proportional to the area of the mirror and is indeed rather high (of the order of 101/s cm$^2$ for oxidizing gases, but much smaller for CH$_4$ or even zero for the noble gases), but decreases somewhat after absorption of a few monolayers. It is obvious that it is always preferable to have a mirror with a large surface area. The gas generated will eventually reach the channel exits at the top and bottom of the panel. By using two wire-type barium getters at the top
and bottom of the panel it is possible to produce about 2 cm² barium mirror per centimetre panel width, containing about 2 mg barium. We estimated the total amount of oxidizing gas generated during panel life, using known ESD desorption rates of glass and the water desorption from glass [8], and found that, for a 26" panel, at most 130 mg Ba is needed for a 10 000 h lifetime. Lifetime measurements on 5" panels showed that we overestimated the amount of gas generated and that even 50 mg will be sufficient for a 26" panel. This amount of Ba is smaller than that used in CRTs of the same size where it is about 250 mg. As mentioned above, gases that are not pumped by the Ba getter are also often present in the panels. Methane in particular may occur, but fortunately it is cracked at the heated cathode wires such that the CH₄ pressure remains small enough to cause no problems. The noble gases are only a problem if the partial pressure comes above 10⁻¹ Pa, which is extremely unlikely, and in practice no problems due to these gases have been encountered.

6. Conclusion

In conclusion it may be stated that although the Zeus panel consists of more parts than other flat panel types, the assembly of the panels is fairly straightforward and does not contain critical alignment steps. The physical processing is critical to a proper functioning of the panels, but it was found that a satisfactory baking and pumping process takes less than 3 h. The small number of connections to the panel makes the use of a very reliable connection method possible.

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REFERENCES