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Brightness Degradation of Projection TV with Plastic Coupler

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플라스틱 커플러를 채용한 프로젝션 TV의 휘도저감

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Abstract In general the cooling of projection TV is realized with aluminum coupler and coolant. A new type of projection TV with plastic coupler is discussed. Compared with an aluminum coupler, the plastic coupler has the advantage of cost, but is not as good as aluminum one in cooling performance. Therefore it is thought that there may be some problems such as brightness degradation induced by insufficient cooling andit is needed to investigate the relation between phosphor brightness and temperature variation. In this paper, a procedure is developed to predict the brightness degradation of CRT in projection TV with plastic coupler. Thermal analysis for CRT in projection TV is performed using FEM (finite element method).

Key words : Projection TV, Brightness degradation, Plastic coupler, Thermal analysis, FEM

요 약 일반적으로 프로젝션 TV의 냉각을 위해서는 알루미늄 커플러와 냉매를 사용한다. 본 연구에서는 비용절감의 차원에서 플라스틱 커플러를 사용하는 경우, 냉각성능 저감에 따른 휘도저감의 문제에 대해 연구하였다. 형광체의 밝기와 온도변화와의 관계를 조사하고, 프로젝션 TV 내 CRT의 온도분포를 유한요소법을 이용하여 해석하였다. 이러한 결과로부터 플라스틱 커플러를 채용하는 프로젝션 TV의 휘도저감을 예측할 수 있었다.

1. Introduction

Projection TV is a display system, which can overcome the size-limitation of the conventional CRT (Cathode Ray Tube). Its operation is very simple, that magnifies the small images to realize a large screen in the conventional CRT. The projection TV has three small CRTs for red, green and blue color(R, G and B CRTs), which correspond to three electron guns of conventional CRT.

Brightness is the most fundamental quality in display devices, which has been investigated by researchers for many years. The brightness of projection TV is dependent upon several factors, that is, the brightness of each CRT, the performance of optical system, the image magnification, and so forth. The simple method to obtain high brightness in projection TV is to make CRTs bigger. Because of the spatial limitation in projection TV, however, the CRTs in projection TV have size-limitation. Figure 1 shows the CRT in projection TV.

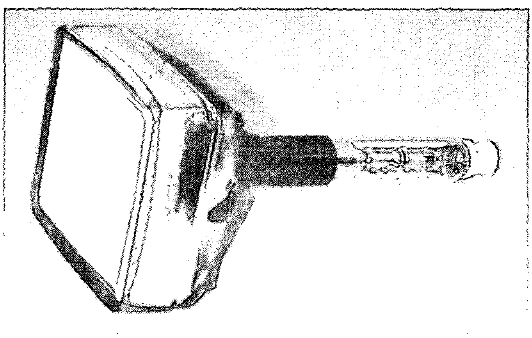

Fig 1. CRT in projection TV

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For high brightness in projection TV, the CRTs in projection TV is operated at a higher anode voltage and a higher current density than conventional CRTs [1]. These operating conditions, however, may induce thermal problems. Because much more electron beams than those of conventional CRTs are bombarded to the panel and these impact energies almost convert heat, the temperature of CRTs in projection TV increases excessively. The undesirable effects due to excessive heat are as follows. First, the brightness of screen has a tendency with degradationbecause the light radiation of phosphor mainly decreases as temperature increase. Second, as the phosphor of each R, G, and B CRT has different chemical ingredients, when the heat generation of CRT panel is excessive, the purity of white-balance of projection TV is degraded. Besides, an excessive temperature increasing causes CRT to be in the unstablestatus structurally.

Up to now, to solve the thermal problems of CRT in projection TV, several cooling methods have been researched. The liquid cooling method using a mechanical coupler is one of the most common and practical methods.The coupler is generally composed of aluminum housing and coolant. Recently we are developing the new type of projection TV with plastic coupler. Compared with the aluminum coupler, the plastic coupler is largely profitable for the cost, but is not as good as aluminum one in cooling performance. Accordingly, it is thought that there may be abrightness problem induced by insufficient cooling and it is needed to investigate the relation between phosphor brightness and temperature variation.

There are few papers concerned with thermally induced brightness degradation of phosphors, which cannot make it clear to describe the direct relationship between phosphor brightness and temperature. Kikuchi et al. [1] and Phosphor Handbook reported experimental dataof phosphor brightness and temperature in references [2]. But these experiments were performed with a particular type of CRT and at room temperature condition, which could not give us general information. Additionally relative brightness of references is corresponding to the temperature at the outer surfaceof panel, which is not directly related to the phosphors themselves. The relative brightness means a ratio of the brightness at a particular temperature to the brightness at room temperature, 25℃.

In this paper, we develop a procedure to predict the thermally induced brightness degradation of phosphors in CRT. Thermal analysis of CRT using the finite element method is performed. For the precise analysis, all heat transfer phenomena (conduction, convection and radiation) are considered. The proposed procedure is applied to the newly developed projection TV with plastic coupler in LG electronics.

2. Simulation

2.1 Assumptions

Thermal field of CRT in projection TV is analyzed in order to predict the thermally induced brightness degradation. The phosphor luminescence results from the collision energy when the electron beam is bombarded to the phosphor on inner surface of panel. Most of the collision energy, more than 90%, is converted to heat, which may deteriorate the performance of CRT such as brightness, white balance and structural stability of a glass bulb, etc. Because the glass bulb is at high vacuum state, heat radiation is a majorheat transfer. The heat transfers outside CRT are divided into two. One is a couple of the heat conduction and the heat convection at the lateral side of the glass bulb. The heat in the lateral side of the glass bulb is transferred to the deflection yoke and to the inner space in projection TV system. The other is heat convection to the coolant filled in a coupler. The structure of projection TV is shown in Fig. 2. The coupler is joined with the optical unit and transfers heat energy to the inner space of projection TV system via heat convection. An analysis considering all parts in the projection TV system is considered to be inefficiently. The simplifications and the assumptions for the thermal analysis are as follows:

- The object of analysis is simplified to CRT in projection TV only.
- Experimental temperature at the outer surface of panel is prescribed as essential boundary conditions.

- The energy generated by electron beam is completely converted into heat energy, though a little portion of beam is used to activate phosphor.
- The heat input per unit area in the panel is obtained from the power of electron gun without any energy loss.

$$q_{in} = \frac{P}{A_{raster}}$$

where

P : power of electron beam

A_{raster} : raster area

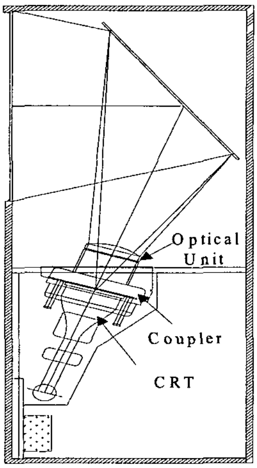

Fig 2. Structure of projection TV

2.2 Brightness degradation of phosphors induced by temperature arising of CRT panel surface

Luminescence mechanism of phosphor is as follows. When phosphor electrons, which are stimulated by electron bombardment, are returning from the activated state to the more stable state, the phosphors emit the light according to the difference of energy level between two states. Figure 3 shows relationship between energy level of phosphor electrons and the distance among them.

If the phosphor electrons at the ground state A absorb the energy generated in collision of electron beam, they rise to the activation state B. The light emission of phosphor appears in transferring from the state B to the state C. Returning to the ground state, the phosphor finishes the luminescence cycle. In the meantime, atoms of phosphor vibrate themselves according to the amount of heat energy. The vibration amplitude has a relation with the width of luminescent spectrum.

The degradation of phosphor brightness induced by temperature increasing in the inner surface of panel is dependent on the chemical ingredients of phosphor. There has not been any research paper about the numerical simulation that clarifies the luminescent mechanism of phosphor at a microscopic level. In this paper, we suggest a procedure to predict the relative brightness degradation of each R, G, and B phosphor based upon the thermal analysis using the FEM program ANSYS [3] and the experimental results provided by Kikuchi et al. [1] and Phosphor Handbook [2].

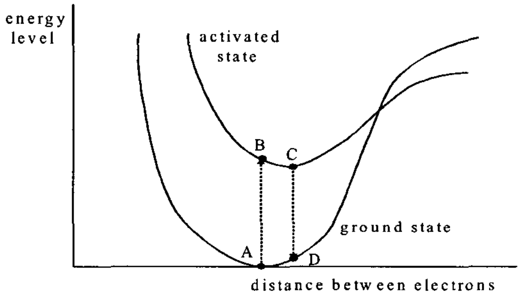

Fig. 3 Mechanism of phosphor luminescence

2.3 Relative brightness of various phosphors

The experimental data provided by Phosphor Handbook are about the relationship between the relative brightness of various phosphors and the temperature not at the inner surface but at the outer surface of panel. Therefore the experimental data have a lack of generality and are only for a particular type of CRT in projection TV. The temperature of the inner surface of panel is deeply related to the phosphor luminescence.

Numerical analysis for obtaining the temperature at inner surface from the temperature at outer surface of panel is performed by using ANSYS, and the relation between the relative brightness of phosphors and the temperature at the inner surface of panel is obtained as shown in Fig. 4. In figure, each symbol represents thechemical ingredient of phosphor.

3. Discussion of plastic coupler

The procedures provided in the prior part of this paper have an object to obtain the relative brightness in currently developing projection TV with new plastic coupler,in LG electronics. Figure 5 shows a plastic coupler. Generally a coupler is made of aluminum alloy due to its goodthermal characteristics. But due to the high cost of aluminum alloy, material change is increasingly required. In changing material, one of the most considerable factors is the thermal property of coupler. Table 1 shows the material properties of CRT with the plastic coupler. It is reported that the heat radiation is a major heat transfer mechanism inside CRT[4]. Therefore, to calculate the heat radiation precisely, reliable value for emissivity should be necessitated. It is difficult, however, to obtain the emissivity of a surface since it is a function of temperature as well as wavelength and surface roughness. In this paper, emissivity of blackened surface of projection CRT is set to 0.7~0.9 according to the measurement [5] of 17" CDT in LG electronics. Table 2 shows the parameters used to an analysis.

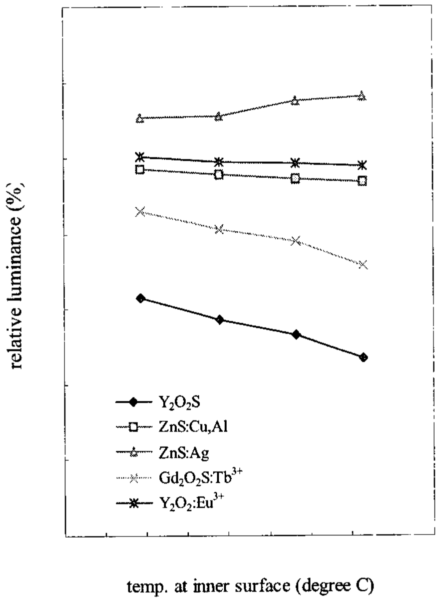

Fig 4. Relative brightness with temperature at the inner surface of panel

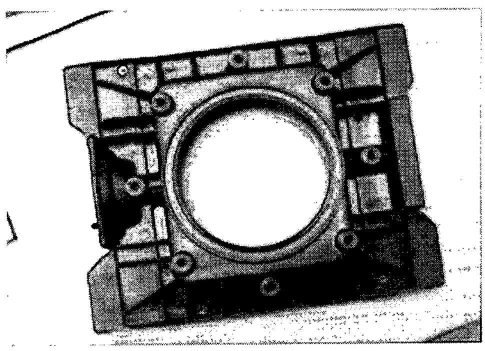

Fig 5. Engineering sample of the plastic coupler

Table 1. Material properties

Material Properties	
Heat conductivity [*W/mK*]	1.007e-5
Specific heat [*J/kgK*]	590
Emissivity for blackened surface	0.8
Density [kg/mm^3]	6.5e-6

Table 2. Loading conditions of analysis

Factors	
Raster Size [mm^2]	110.762.3 = 6896.6
Anode Voltage [*kV*]	31.5
Anode Current : long term [*mA*]	0.5
Electron Gun Power [*W*]	15.75
Heat Flux [$W/\ mm^2$]	2.28e-3

The temperature of the outer surface of panel contacting with coolant is fixed with the measured data, 77℃, of LG WP4600 projection TV. The lateral side of CRT in the projection TV is assumed to have convection heat transfer at 40℃, measured in the experiment, too. Figure 6 shows a steady-state thermal distribution of CRT operating at a normal test condition. The analysis method to calculate a thermal distribution of CRT is explained in Ref.[5]. It shows that the maximum temperature of panel surface reaches to about 100℃.

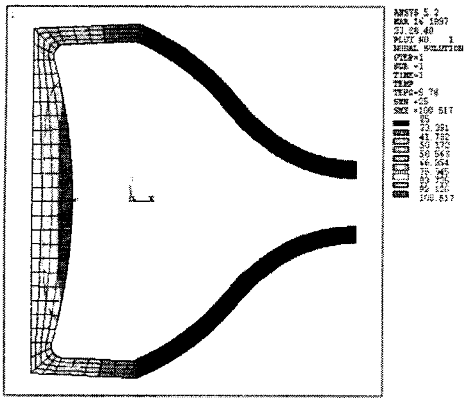

Fig 6. Temperature distribution of the projection CRT at a steady state

With the analyzed temperature and the graph provided in Fig. 4, the relative brightness of each R, G, B phosphors at an steady state is obtained: the brightness of Gd2O2S:Tb3+(green) is decreased to about 80% comparing to the early stage of operation and the case of Y2O3:Eu3+(red) is about 98%, whose temperature dependency is very small, but the case of ZnS:Ag (blue) is increased to about 115% on the contrary. It is known that the brightness of green phosphor has adominant role, about 70%, on the white balance condition of CRT. Therefore it is considered that there islittle significant degradation of white balance at a normal test condition, though the cooling performance of plastic coupler is inferior toaluminum one. Table 3 shows the selective results at the various temperature conditions. Thermal distribution is almost same as Fig. 6. In the case of green phosphor, relative brightness becomes to be decreased to about 60% at 120℃ on the inner surface of panel (about 100℃ on the outer surface of panel). If temperature at the inner surface of panel exceeds 120℃, the white balance will be degraded in quality. Therefore it is found that the temperature on the outer surface of panel should not exceed about 90℃ with a view of white balance.

Table 3. Selected relative brightness of various phosphors with temperature

Temperature at center point (℃) outer surface	inner surface	Relative brightness (%)		
		Gd2O2S:Tb3+(G)	Y2O3: Eu3+(R)	ZnS: Ag(B)
80	103.1	78	99	115
85	107.3	76	99	116
90	111.6	72	98	117
95	115.8	69	98	117
100	120.0	64	97	118

4. Conclusions

The following conclusions can be drawn from the study.

1) The analysis procedure in this paper can predict the relative brightness degradation of CRT in projection TV with various R, G, B phosphors induced by temperature increasing at the inner surface of glass panel using the FEMand the experimental data provided by Phosphor Handbook [2].
2) The proposed analysis was applied to the projection TV with a plastic coupler in LG electronics. At a normal test condition, relative brightness of each R, G, and B phosphor is calculated to 98%, 80%, and 115%. It is considered that there will not be an extremely severe degradation of white balance, though the heat transfer properties of plastic coupler are inferior to aluminum one.

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