Voltage Dependence Curves of Cathodoluminescence of $Y_2O_3S:Tb$ Phosphor Screen

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It has been found that a phosphor screen, composed of $Y_2O_3S:Tb$, in 0.6 inches CRT exhibits two distinctively different slopes in voltage dependence curve of the cathodoluminescence excitation; e.g. above and below a 3 keV potential. These difference in the voltage dependence curves of the cathodoluminescence may be attributed to an involvement of a piezoelectricity of the phosphor crystals under irradiation of the electrons.

Key words: CRT, phosphor screen, piezoelectricity, cathodoluminescence.

1 INTRODUCTION

Attention has been focused on a phosphor screen used in a minitature projection CRT of less than 1 inches which exhibits a high brightness of 1,000 cd/m² along with a substantial resolution of 700 TV lines horizontally⁽¹⁾. The phosphor screen consists of $Y_2O_3S:Tb$ phosphor particles, which emit a white cathodoluminescence(CL) when excited by electrons slightly above 1 keV. This miniature CRT has been selected for usage in portable video cameras as a view finder after difficult competition from liquid crystal display (LCD) and vacuum fluorescent display (VFD), because of its high resolution of real time images, low power consumption and light weight⁽²⁾.

2 VOLTAGE DEPENDENCE CUURES OF CL

We have studied emission intensities of the $Y_2O_3S:Tb$ phosphor screen as a function of anode voltages of the miniature CRT; i.e. voltage dependence curves of CL, for optimization of the phosphor screens. The voltage dependence curves of phosphor screens have been investigated by many authors^(3,4) in both CRTs

and demountable instruments. Results of these investigation have typically indicated a dead voltage of 2 or more keV, and it was not clearly shown what the critical anode potential applied had rendered CL. In our investigation, we have found that these critical anode voltages to generate CL of the phosphor can be clearly determined from the voltage dependence curves if the measurements

Fig.1 Voltage dependence of $Y_2O_3S:Tb$ phosphor screen in 0.6 inches CRT

are made on the phosphor screen in 0.6 inches CRTs.

The phosphor screen of $Y_2O_3S:Tb$, which have the average particles size in $2.7 \mu m$ by microscope, are deposited on a glass substrate. The screening density of the phosphor powder was $1.0 mg/cm^2$ in coverage. The screened 0.6 inches face plate was seated onto a miniature CRT, and the electron beam was magnetically focused onto the screen with a spot size of $20 \mu m$. The emission intensities were measured by the rastered electron beam. Fig.1 shows the voltage dependence curves obtained with two different levels of current; one at $4 \mu A$ and the other at $10 \mu A$. The curves at the given electron beam current fit on the straight lines, but consist of two slopes, above and below 3 keV. With a given electron beam, the curve for above 3 kV anode voltages has a large slope as compared with the slope below 3 kV. At the zero CL intensity, the curves of the different electron beams are converged to two anode voltages; e.g. around 2.4 and 0.9 kV. We have observed the similar curves, not shown in Fig.1, with the different electron beam current levels.

3 OBSERVATION OF PHOSPHOR SCREEN UNDER SEM

In order to understand these 2 slopes in the voltage dependence curves, further screen studies were performed using a scanning electron microscope (SEM) at anode voltages. It was found that the phosphor particles would physically move together (agglomerate) when exciting electrons were accelerated beyond 3 keV, and at 2.5 keV or less, the particles would remain unchanged in location where originally settled. Fig.2 shows the SEM photomicrographs ($\times 5,000$) of the particles under irradiation of the electrons of the energy of 1 keV(A), and 10 keV(B). It can be noted that many particles have moved in the

irradiation of 10 keV electrons. But, by applying a gold film of $500 \text{ \AA}$ in thickness over the particles, all movement of the particles has stopped. The SEM photomicrographs (C) and (D) in Fig.2 show no movement under 2 keV and 10 keV electrons, respectively, when the particles are covered with Au film. Photomicrographs at 1 keV acceleration could not be obtained with the SEM. Our conclusion drawn from these experiments are that the Au film is physically attached and holding the particles in place, and that the Au film is removing the surface charges on the particles during electron irradiation.

4 DISCUSSION

The movement of the particles under irradiation of the electrons may be directly related with the piezoelectricity of the phosphor particles.⁽⁵⁾ Since Y_2O_3S crystals have a lack of center of symmetry, they should demonstrate a piezoelectric capability. The crystals also exhibit piezoelectricity under irradiation of the particles which have an energy greater than the band gap⁽⁶⁾; e.g. photons and electrons. The experimental phosphor particles (crystals) are settled on the glass substrate with a very weak binding force, like as van der Waals force. Therefore, if the energy of electrons colliding on the particles is low to generate a piezoelectric force, the particles will not move because the binding force is stronger. But if the piezoelectric deformation force exceeds the binding force, the particles can move on random directions from their initial settled location. The experiments showed a threshold voltage of 3 keV to move the Y_2O_3S particles. It was also observed that an application of a thin film of Au on the phosphor screen prevented these particle movements. The phosphor screens were rapidly burned under irradiation of the electrons of

Fig. 2 Photopictures of SEM ($\times 5,000$ magnifications) of $\text{Y}_2\text{O}_2\text{S:Tb}$ phosphor particles under irradiation of 1 keV (A), 10 keV (B) electrons and of the particles covered with Au thin film (500 Å) under irradiation of 2 keV (C) and 10 keV (D) electrons.

the energy greater than 3 keV. The burning was resisted if the screen were under a bombardment of the electrons of the energy smaller than 2.5 keV. Thus the burning of the screens may be correlated with the catalytic action of piezoelectricity of the phosphor particles.⁽⁷⁾ Further study is underway.

5 CONCLUSION

It can be said from above experimental results that if one uses the white emitting $Y_2O_2S:Tb$ phosphor screens in 0.6 inches CRT, there are two kinds of the phosphor screens, depending on the anode voltages of the CRTs; above and below 3 keV. If the anode voltage of the CRT is below 3 keV, the electron beam from electron gun may irradiate directly on the phosphor screen which has no metal-back film. This conclusion is applied to the phosphor screen in 0.6 inches CRT for viewfinder of portable video camera which anode voltage is 2.2 keV, and which the brightness of the phosphor screen is approximately 100 cd/m². However if one wishes to have a phosphor screen brighter than 300 cd/m², the phosphor screen must be irradiated with the electron beam having the energy greater than 3 keV. In this case, a metal-back film on phosphor screen at gun side is an absolute necessity to avoid a poor resolution of the images caused by migration of phosphor particles in the screen.

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