Color Simulation to Demonstrate the Effects of the Filter Layer with $CoAl_2O_4$ on Inner Face of CRT Panel

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Abstract

Nanosize cobalt aluminate($CoAl_2O_4$) power was coated as filter layer for us to improve the color purity and contrast performances on the inner face of CRT panel. We simulated color properties by measuring the transmittance and thickness of the coated filter layer. Contrast performance could be improved and color gamut was also changed by the selective light absorption of filter layer at 580~605 nm.

Keywords : $CoAl_2O_4$, filter layer, panel, color simulation, CRT

1. Introduction

With the advancement of information technology, many kinds of display devices such as CRT, Organic LED, Inorganic LED, TFT-LCD, PDP, FED, etc., have recently been developed and introduced. The advantageous of these display devices are superior brightness, its uniformity, higher contrast, better color purity and wider color gamut. CRT is well known as an outstanding display device with the best screen performance. CRT based on screen performance and HDTV technology will be developed to slim CRT and will continue to be the a long time.

To be like this, good color reproducibility and higher contrast as screen performance are the essential features in CRT [1~8]. This paper reports about the effects of the filter layer coated with $CoAl_2O_4$ on inner face of CRT panel through color simulation.

2. Experiment

3 weight percentage of the particulate nanosize cobalt aluminate($CoAl_2O_4$) sol including silica as inorganic binder was used. This sol was spun out on soda lime glass and was dried. As a result, a filter layer with cobalt aluminate was formed. Clear CPT panel with a thickness of 12.0 micrometer was used in the color simulation. Scanning electron microscopy(JSM-6300, JEOL, Japan) was used for evaluating the particle size of cobalt aluminate in the filter layer. Transmittances of the filter layer and CPT panel were measured by a UV spectrophotometer (UV2100, Shimadzu, Japan), cathodoluminescence of R, G, B phosphor was measured by colorimeter(PR650, Photo Research , U.S.A).

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3. Results and Discussion

Fig. 1 shows the SEM micrograph of the cobalt aluminate powder on the filter layer.

It can be seen that the particles are almost spherical in shape and about 70 nm in size.

Fig. 2 shows the results of the simulation for the transmittance of filter when layer it was formed in inner face of panel.

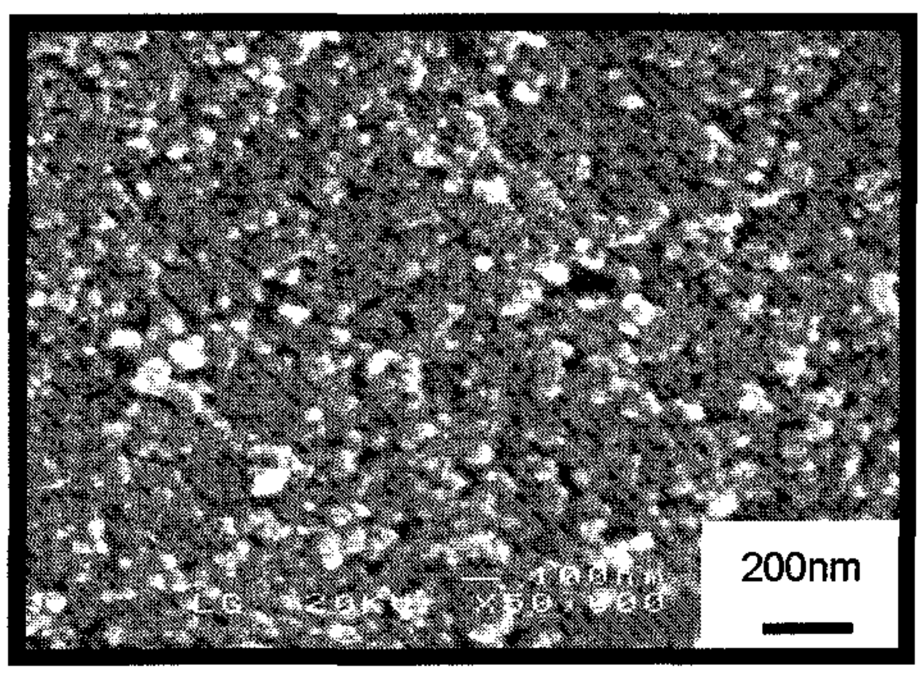


Fig. 1. SEM micrograph of the cobalt aluminate powder on the filter layer.

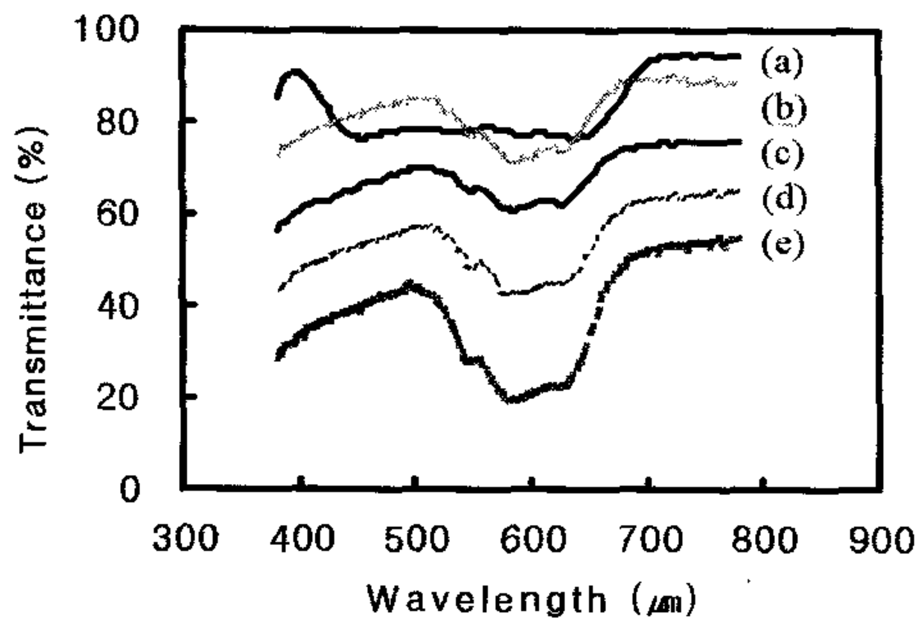
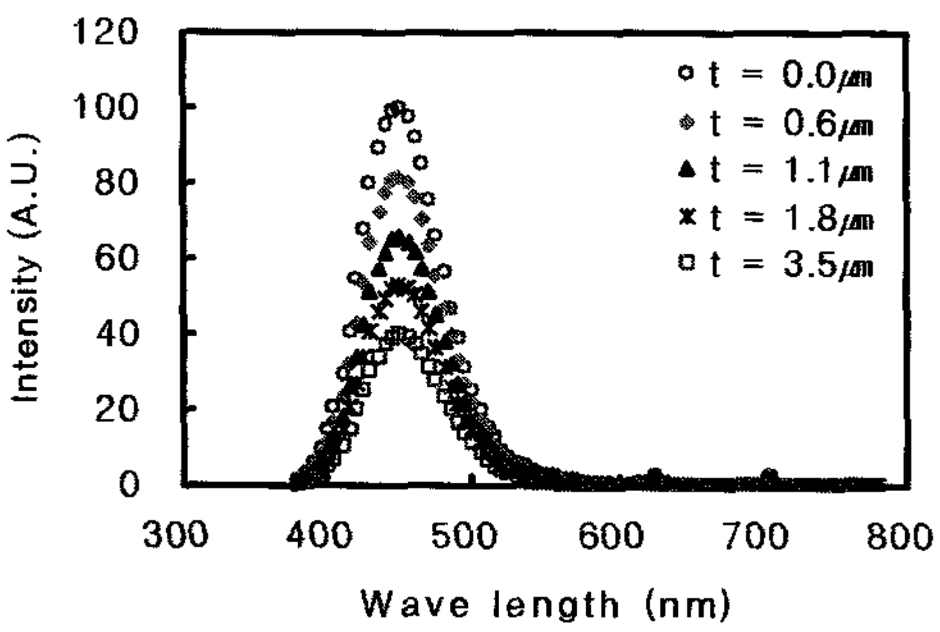
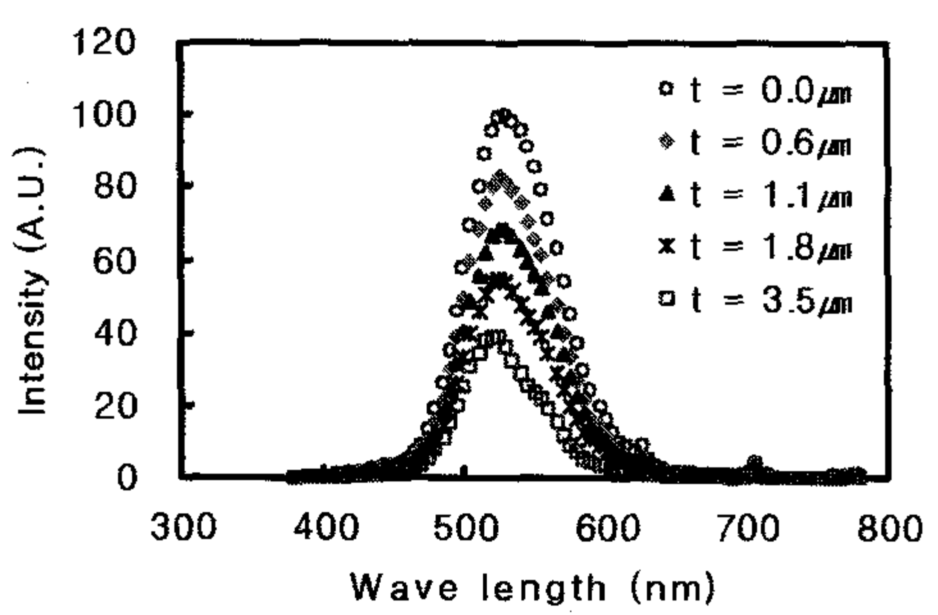


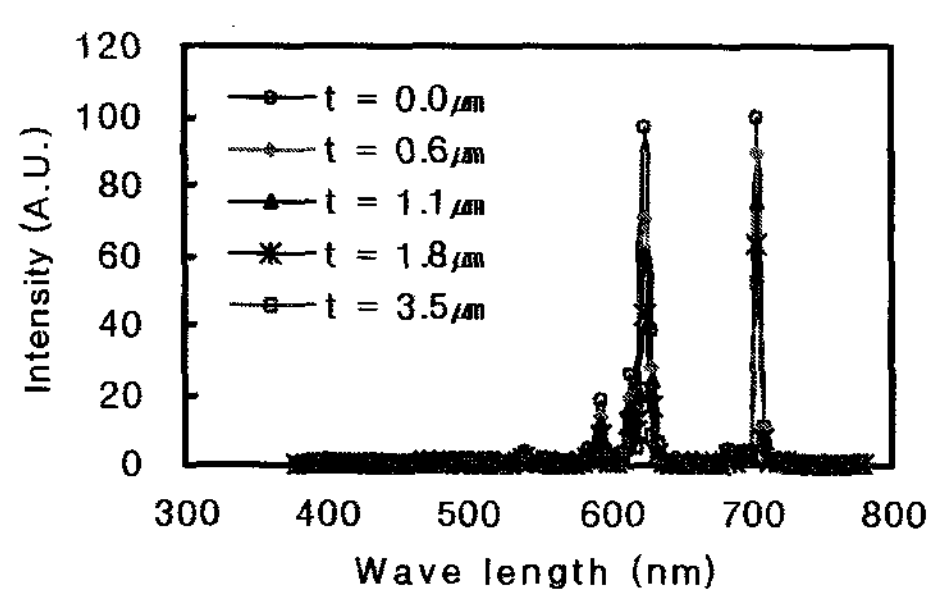
Fig. 2. The transmittance for the panel with inner filter layer made of cobalt aluminate. (a) as-received clear panel, (b) t = 0.6 ㎛, (c) t = 1.1 ㎛, (d) t = 1.8 ㎛, (e) t = 3.5㎛



(a)



(b)



(c)

Fig. 3. The emission spectra according to the coated thickness of cobalt aluminate in CRT. (a) Blue (b) Green (c) Red

Transmittance was calculated as follows.

Transmittance = $T_{Panel} \times T_{Filter}$

T_{Panel} : Transmittance of panel

T_{Filter} : Transmittance of filter layer = $T_{sodalime\ glass\ coated\ withCoAl2O4} / T_{sodalime\ glass}$

$T_{sodalime\ glass\ coated\ withCoAl2O4}$: Transmittance of sodalime glass with filter layer

$T_{sodalime\ glass}$: Transmittance of sodalime glass

Clear panel shows about 79% of the light transmission property which is perceivable to the human eyes at the range of 445 ~ 650 nm as Fig. 2 (a). From this figure, it can be seen that when cobalt aluminate inner filter layer is formed on the inner face of CRT panel, a decrease of panel transmittance is observed at the range of 505 ~ 680 nm. The greatest decrease in transmittance is shown at the range of 580 ~ 605 nm which is at the boundary between the range of green and that of red color and shows orange color as shown in Figs. 3(b) ~ (f). It is thought that selective light absorption at special wavelength range such as 500 ~ 680 nm is a distinctive feature of filter layer with cobalt aluminate.

Fig. 3 shows the results simulated for the cathodoluminescence of CRT when filter layers were formed on inner face of panel.

Cathodoluminescence spectra were calculated as follows.

Spectrum = $S_{phosphor} \times T_{panel\ with\ filter}$

$S_{phosphor}$: Emission spectrum of phosphor

$T_{panel\ with\ filter}$: Transmittance of panel with filter layer.

From Fig. 3, it can be seen that as the thicknesses of filter layer increases, the emission intensities, which indicates the brightness of R, G, B color, decrease as a whole. The shoulders of spectrum, in particular, are shifted from 530 nm to 515 nm and green peaks at the range between 705 ~ 710 nm decrease in case of green spectrum as shown in Fig. 3(b). This is due to the transmittance of panel decreasing as a result of the selective light absorption of filter layer at the special range of wavelength as shown Fig. 2.

Fig. 4 shows the results of the simulation of the change of the chromaticity coordinate when CRT with filter layers was used.

Chromaticity coordinate was calculated as follows.

$$x = X / (X+Y+Z)$$
$$y = Y / (X+Y+Z)$$

$$X = \sum_{i=380}^{780} S(\lambda)x(\lambda)T_{panel*Filter} \cdot \frac{100}{\sum_{i=380}^{780} S(\lambda)y(\lambda)}$$

$$Y = \sum_{i=380}^{780} S(\lambda)y(\lambda)T_{panel*Filter} * \frac{100}{\sum_{i=380}^{780} S(\lambda)y(\lambda)}$$

$$Z = \sum_{i=380}^{780} S(\lambda)z(\lambda)T_{panel*Filter} * \frac{100}{\sum_{i=380}^{780} S(\lambda)y(\lambda)}$$

S(λ) : Each emission intensity of R,G,B phosphor ×**ik** of each R,G,B cathode in CRT.

x(λ), y(λ), z(λ) : Color matching function in XYZ color system.

$T_{panel*filter}$: Transmittance of the panel coated with filter layer composed of cobalt aluminate.

Once filter layers are formed on the inner face of a panel, chromaticity coordinates for blue color almost do not change. However, those for green color are shifted to pure green and those for red color show the tendency of being shifted to white red as shown in Fig. 5. This is believed to be due to the selective light absorption of filter layer at orange color range between 580 ~ 605 nm.

Fig. 5 shows the schematic image of about the reflectance of incident light from outdoors into panel.

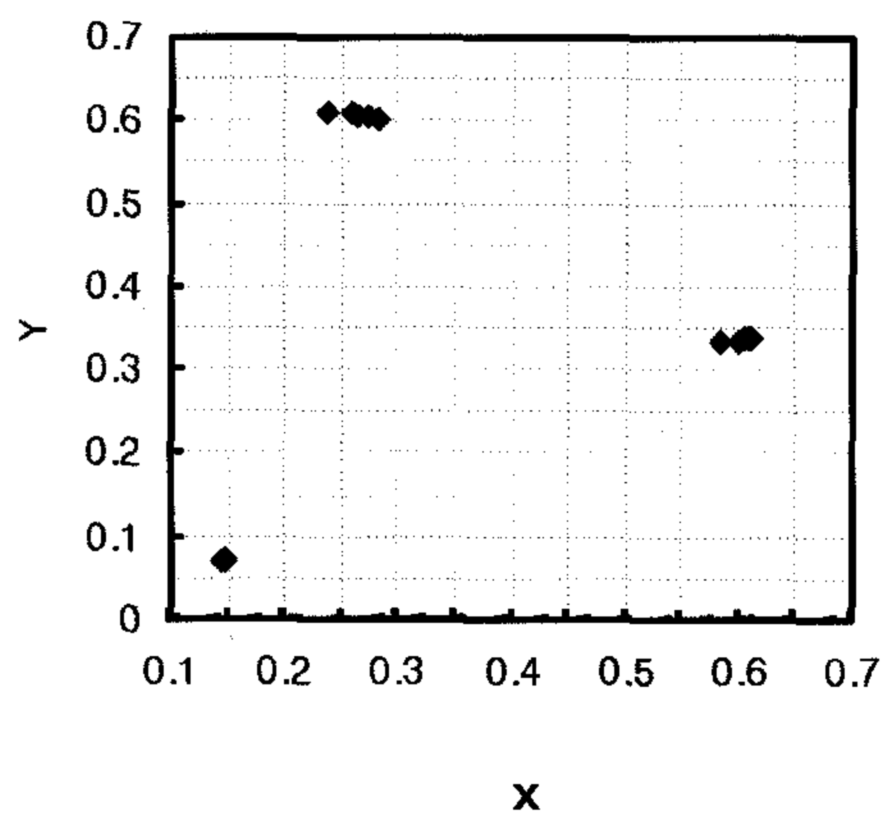


Fig. 4. The change of chromaticity coordinate according to the thickness of filter layer in CIE 1931 chromaticity diagram.

It can be seen that the reflection of incident light into screen occurs on panel face, black matrix, inner filter layer and phosphor coating as shown in Fig. 5.

In this case, the contrast of CRT can be calculated as follows.

Contrast = (Average brightness + Total reflected light) / Total reflected light

Total reflected light

= Reflected light at BM + Reflected light at Phosphor layer + Reflected light at Panel face

Reflected light at BM = (L/π * 0.2919) * (1-R_{Glass}) * T^2_{panel} * R_{BM} * * PBMA

Reflected light at Phosphor layer =

(L/π * 0.2919) * (1-R_{Glass}) * T^2_{panel} * $T^2_{filter/}$ * $R_{Phosphor}$ * (1-PBMA)

Reflected light at Panel face = (L/π * 0.29) * 0.045

Phosphor reflectance

= (Red phosphor reflectance + Green phosphor reflectance + Blue phosphor reflectance)/3 ≒ 0.61

R_{Glas} : Reflectance of glass surface
R_{BM} : Reflectance of graphite layer
$R_{Phosphor}$: Reflectance of phosphor
L : Brightness of outdoor light (lux)
PBMA : Percentage of black matrix area in screen.

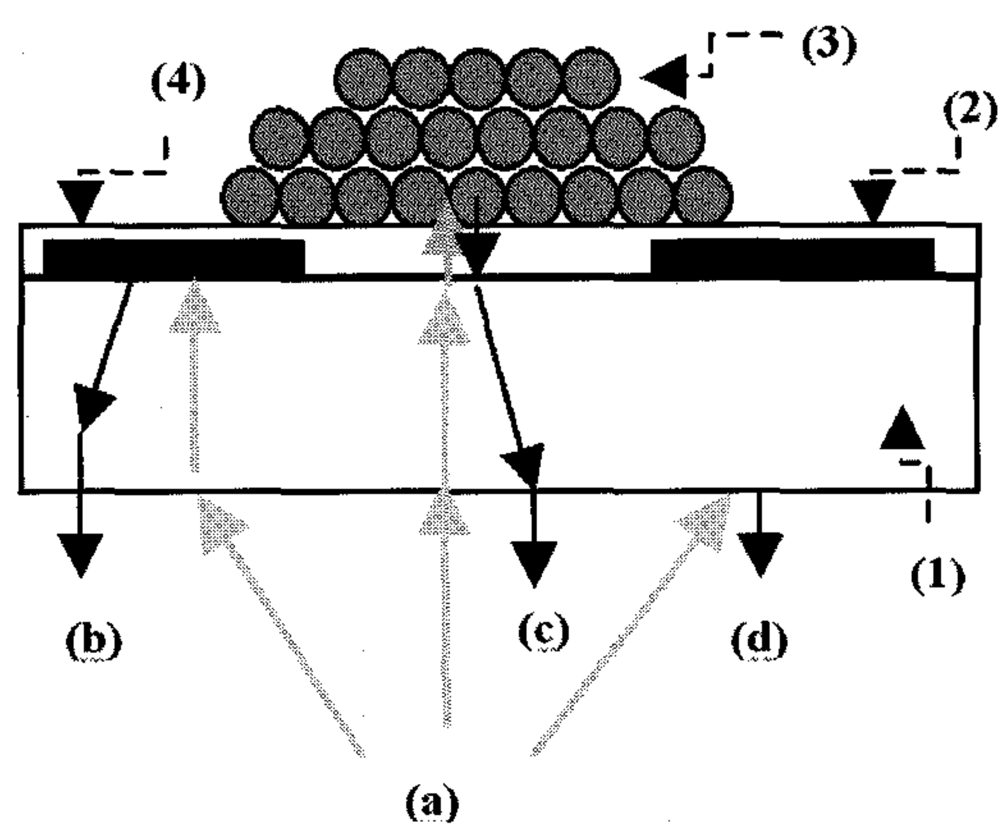


Fig. 5. Schematic figure for the reflected light from the CRT screen.
(a) Incident light from outdoors (200 lx)
(b) Light reflected from black matrix
(c) Light reflected from phosphor
(d) Light reflected from panel face
(1) Panel (2) Black matrix (BM)
(3) Phosphor (4) Inner filter layer

Here, 45FL was taken as the average brightness, the unit of L is lux, (1Lux = 1/π cd/m^2 = 0.2919/π FL), 200 lux was used as the L value, and R_{BM} which was measured by a colorimeter(CS-1000, Minolta) was 0.057. "1-PBMA" is generally called as screen transmission and the value of PBMA was set as 0.4, and R_{Glass} was set as 0.045.

Fig. 6 shows the changes of contrast simulated by using above equations.

The contrast increases as the thickness of filter layer increases. This assumed to be due to total reflected light that decrease due to light absorption of filter layer.

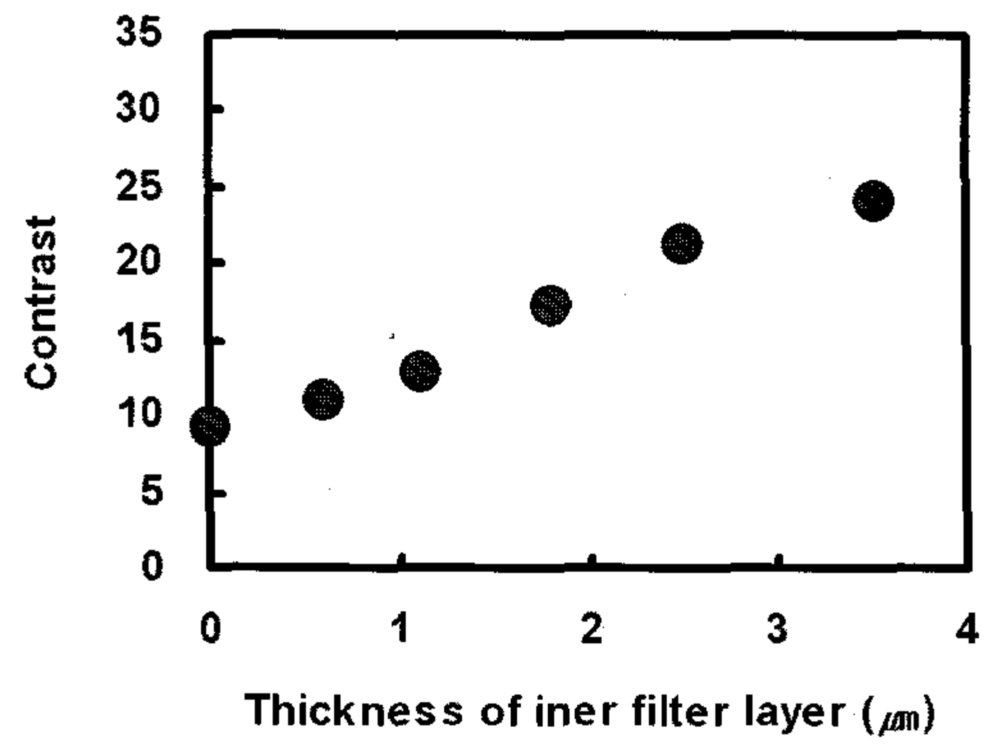


Fig. 6. The change of contrast according to the coated thickness of cobalt aluminate($CoAl_2O_4$) in CRT.

4. Conclusions

70 nm of cobalt aluminate was used in forming filter layer on the inner face of panel. The results show that transmittance of panel and brightness of CRT decrease with increase of thickness of filter layer, the chromaticity coordinates of the green and red color changed and contrast increase as the thickness of the filter layer increases. These results are presumably due to the selective light absorption of filter layer with cobalt aluminate at orange color range between 580 ~ 605 nm.

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