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COLOUR COORDINATES OF SOME PHOTOLUMINESCENT MATERIALS

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Calculation of the colour coordinates using spectrophotometer for various phosphor materials is given. Blending of the components for 6500K daylight phosphor is discussed. Colour coordinates for various phosphor materials are presented.

Key wort s: Phosphor materials, colour coordinates, chromaticity triangle

INTRODUCTION

Phosphors used in fluorescent lamps, high pressure mercury vapour lamps, and CRT screens have their own characteristic emission peaks and band widths in accordance with the nature of the luminescent centres responsible for their emission such as a composite emission band due to Sb^{3+} , Mn^{2+} in $3Ca_3(PO_4)_2$ $Ca(F,Cl)_2$ [1] or a broad band due to a spin flip transition of d-electron of Mn^{2+} in Zn_2SiO_4[2] or a charge transfer mechanism in $CaWO_4$ or a narrow $^5D_0 \longrightarrow {}^7F_2$ transitron of f-electron of Eu^{3+} in Y_2O_3, but the presence of yellow-orange emission due to $^5D_0 \longrightarrow {}^7F_1$ of Eu^{3+} in YVO_4, Y_2O_2S makes them unsuitable for fluorescent lamp applications [3,4]. Since these fluorescent materials are used in various sources of illuminants in conjunction with spectral response of visual system comprising of three photosensitive receptors, it is imperative that the choice of the material should yield optimum brightness with better colour rendition characteristics.

As it is always desirable to have a phosphor system of high light output without compromising much on colour rendition properties, it is essential that the emission spectrum of the system should be quantified in terms of numerical specifications given to each colour rendering indices.

CHROMATICITY TRIANGLE

Calculation of colour coordinates is based on the formulations of CIE (Commission Internationale de l' Eclairage) system laid in 1931 underlying that human visual system is constituted by three photosensitive receptors corresponding to the three primary colours (viz.) red, green and blue represented by $\bar{x},\bar{y},\bar{z}$ as their range of 380-770 nm as perceivable by a standard observer. These standard curves are shown in Fig.1.

An interesting feature of the system is that the sensitivity curve for the green receptor (y) is found to follow the visibility function or luminosity curve from which luminosity for the given wavelength range can be calculated from the relation

$$I = 685 \int P(\lambda)\,\bar{y}\,d \qquad \dots (1)$$

where $P(\lambda)$, $d\lambda$ being the spectral power distribution and wavelength range respectively. $\bar{y}$ being a tristimulus value for the given region with $\bar{y}$ = 1 for the maximum sensitivity at 555 nm corresponding to 685 lumens for 1W of radiant energy.

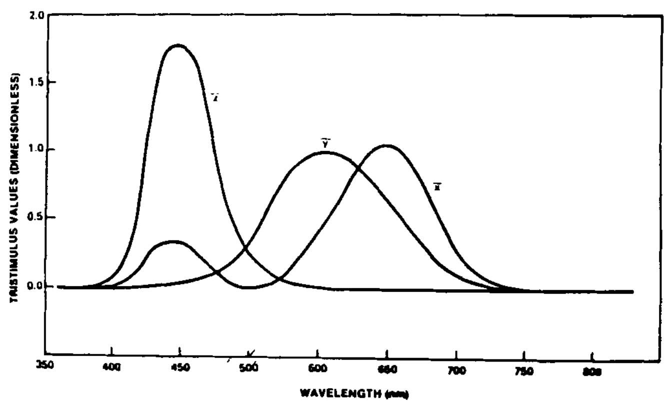

Fig. 1: Spectral tristimulus values according to the 1931 CIE standard observer

Calculation of colour coordinates is based on the fact that any given colour of an emitting system is the composite of three primary colour components having their own relative weightage and bandwidths. These receptors cause photocurrents equivalent to X, Y, Z respectively in accordance with the response curves for red, green, blue receptors. To find the photocurrent for a receptor, we have to multiply its intensity in a particular region by its corresponding sensitivity in that region. When this is extended, the sum of the products for the entire region of visible spectrum would give the photocurrent caused by the light source of interest for the particular receptor. Colour coordinate corresponding to a particular receptor is given by the ratio between the photocurrent of the receptor and the sum of the photocurrents (X, Y and Z) of the three receptors, viz.

$$\text{Red colour coordinate } x = X/(X+Y+Z)$$
$$\text{Green colour coordinate } y = Y/(X+Y+Z) \text{ and} \qquad \dots (2)$$
$$\text{Blue colour coordinate } z = Z/(X+Y+Z)$$

Also the fact that the sum of these chromaticity values $x+y+z=1$ enables us to have a two dimensional graphical representation of any colour perceivable by human eye on a x-y plot called as Chromaticity Triangle, the third value z can be inferred from the values of x, y, the centre point being the white point corresponding to x = 0.33; y = 0.33.

In the x-y plot, it is customary to express a colour in terms of colour temperature of black body called as Correlated Colour Temperature (CCT), which can be found by finding the point of intersection on the blackbody locus as shown in Fig.2, or having closer colour match to the point corresponding to that of particular blackbody colour temperature. The colour of the light is permitted to be deviated from that of the blackbody colour temperature as long as the coordinates of the colour lie within the tolerance ellipse defined for the given colour temperature. To illustrate this, a tolerance ellipse for a colour temperature of 6500K is given in Fig.3.

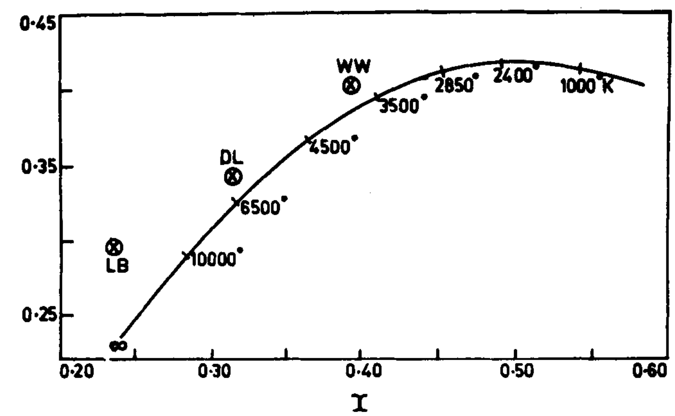

Fig. 2: Graphical representation of Warm White (WW) and Light Blue (LB) components on the black body locus

This procedure of finding colour coordinates for a light source can be extended to find the colour rendering index (CRI), which is a measure of ability to reproduce or reflect objects of various colours to be illuminated without any serious colour distortion [5].

EXPERIMENTAL

All the measurements are made with U-3400 HITACHI Double beam UV-VIS-NIR spectrophotometer fitted with Hammamatsu R928F photomultiplier tube. For carrying out photoluminescence measurements, a mercury discharge lamp is used as exciting source with band pass filter of 250 nm maximum and the fluorescent output is fed to the spectrophotometer by using it in single beam mode. Necessary correction for the spectral response of the photomultiplier and the grating are effected to get the normalised spectral energy distribution (SED) of a given phosphor. This SED is divided into equal intervals of 10 nm in the range 380-770 nm and the data is used to calculate the colour coordinates as described earlier.

BLENDING OF EMISSION BANDS

In dichromatic fluorescent lamps of 6500K the phosphor used is

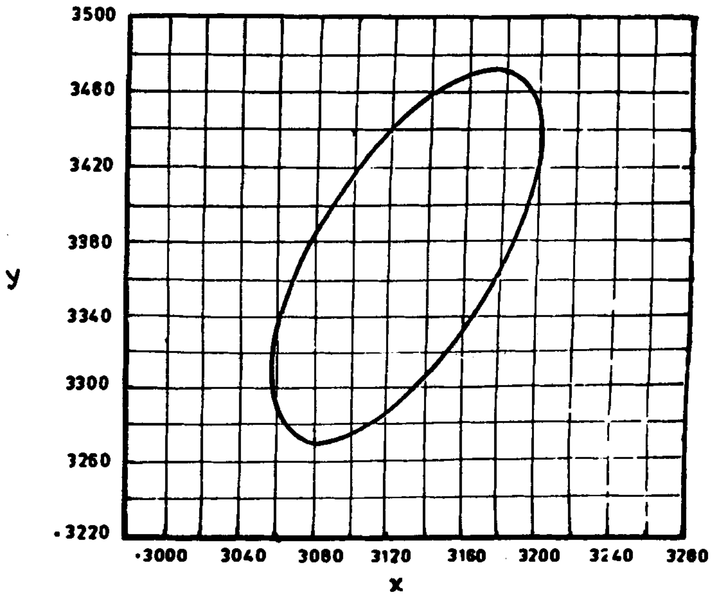

Fig.3: Tolerance ellipse for colour temperature of 6500K

calcium halophosphate: Sb^{3+}, Mn^{2+}, which has the composite emission due to Sb^{3+} and Mn^{2+} in this system. It is the ratio of blending of the two emission bands due to Sb^{3+} activated halophosphate giving light blue (LB) emission and Sb^{3+}, Mn^{2+} activated halophosphate giving warmwhite (WW) emission, that decides the colour temperature and CRI.

Any colour temperature that lies in the line joining the points LB, WW (Fig.2) is possible by proper choice of the blend. But the point to be borne in mind is that the blend should yield optimum brightness with better colour rendition property. The 6500K daylight emission is formed by the blend of the two components viz. the combination of the two photongaussian distributions, with mercury lines of the discharge column.

For optimal condition, the combination can be computed taking into consideration the role of emission peak and bandwidth as illustrated in Fig.4. The effect of these two components of various bandwidth has been thoroughly discussed [6] based on laws of colour addition. Given in Table I are the colour coordinates of some of the commercial phosphors developed by the phosphor group in this Institute. Spectral energy distribution of the phosphors are presented in Fig.5.

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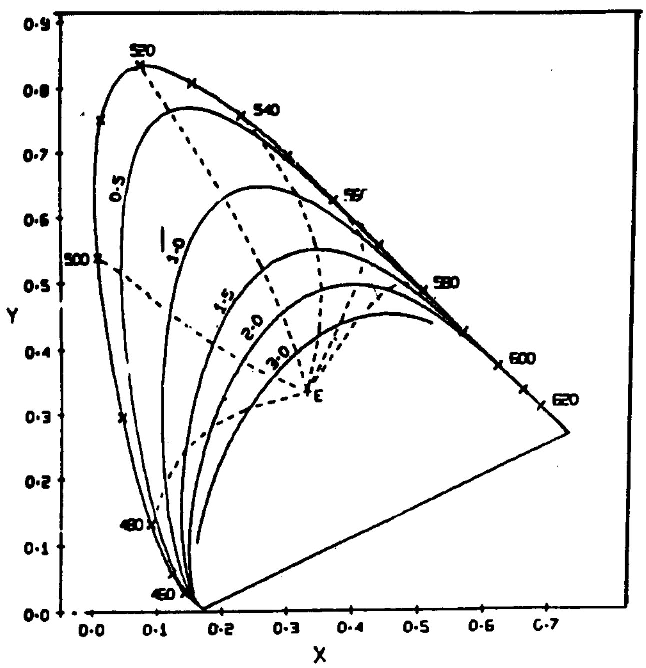
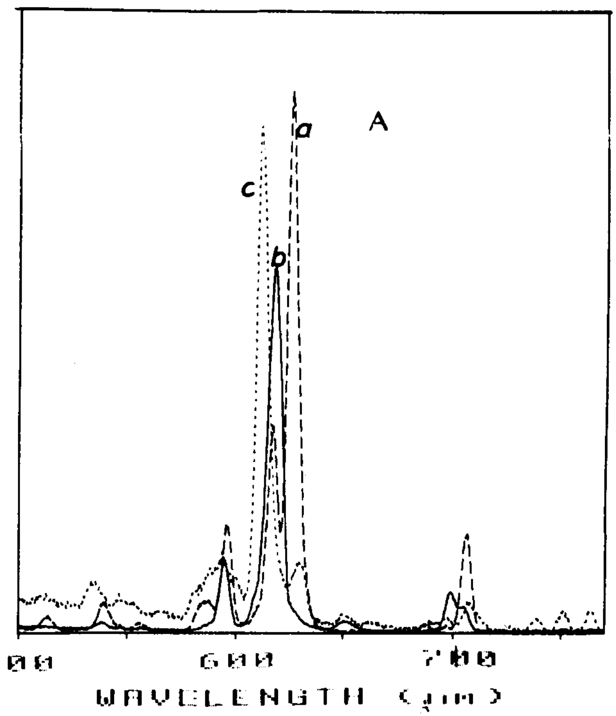
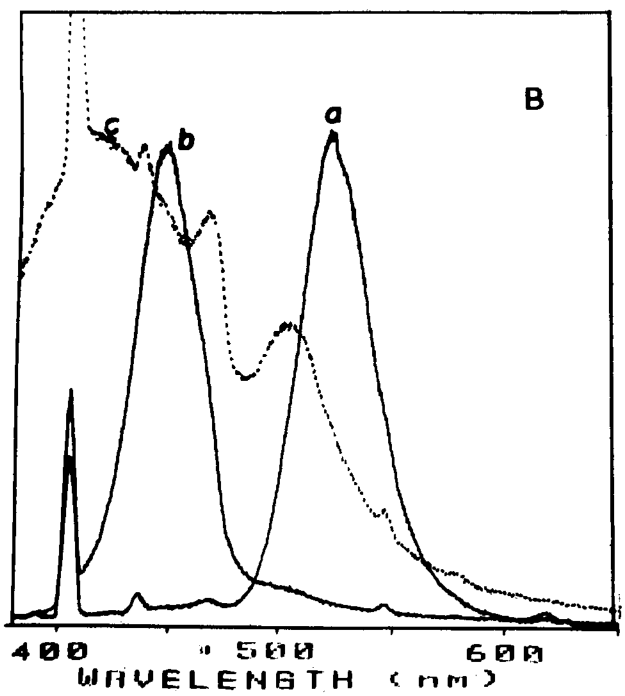


Fig.4: Chromaticity diagram for photon-gaussian spectral emission distribution. The solid lines are curves of constant band width, while the dashed lines represent constant peak wavelength. E is equal energy point [6]



5 (a)



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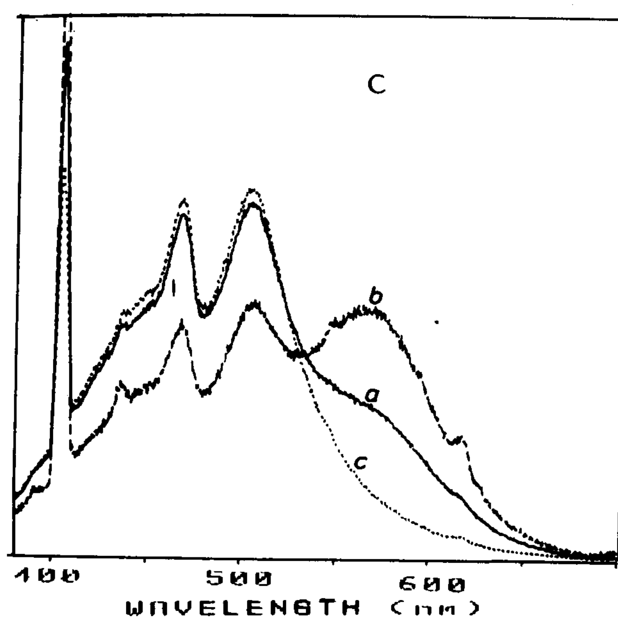

5 (c)

Fig. 5: Spectral energy distribution (uncorrected) of (A) $Y_2O_2S:Eu^{3+}$ (a), $YVO_4:Eu^{3+}$ (b) and $Y_2O_3:Eu^{3+}$ (c); (B) $Zn_2SiO_4:Mn^{2+}$ (a), $Sr_5(PO_4)_3Cl:Eu^{2+}$ (b) and $CaWO_4$ (c); (C) Daylight(a), Warm White (b) and Light Blue (c)

TABLE-I

Phosphors	Colour	Colour coordinates		Application
		x	y	
$Y_2O_3:Eu^{3+}$ (4%)	Red	0.638	0.349	Trichromatic lamp & CRT
$YVO_4:Eu^{3+}$ (5%)	Red	0.658	0.327	HPMV lamps
$Y_2O_2S:Eu^{3+}$ (4%)	Red	0.468	0.336	CTV screens
$Zn_2SiO_4:Mn^{2+}$	Green	0.209	0.708	CRT screens
$Sr_5(PO_4)_3Cl:Eu^{2+}$	Blue	0.152	0.027	Trichromatic lamps
$Ca_5(PO_4)_3(F, Cl):Sb^{3+}Mn^{2+}$	Warm white	0.392	0.401	Dichromatic lamps
$Ca_5(PO_4)_3$ (F, Cl):Sb^{3+}	Light blue	0.231	0.295	,,
53% Warm white + 47% Light blue	Day light	0.309	0.343	,,

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