From White to Magenta

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ABSTRACT

This paper presents two colours, white and magenta. From physical point of view white has the high level of luminosity, no saturation and no hue. By application of fluorescent whitening agents (FWA's) white surfaces can reach great whiteness and brightness but in same time its spectral characteristics move slightly from achromatic point (AP) towards the blue spectrum of chromaticity diagram. In this paper, chemically bleached cotton fabrics is treated with stilbene derivate based fluorescent whitening agents and their whiteness degrees, spectral characteristics and relative intensity of fluorescence are presented. On the other hand magenta spreads to a large extent of spectrum by bridging two ends of a spectrum, the red and blue, different in their frequency and absorption energy. In this paper the analysis of one specific magenta colour will be performed from the aspects of spectral characteristic, specific energy and given specific wavelength of absorption.

KEYWORDS: Whiteness, Colour Luminance, Fluorescence

INTRODUCTION

Over the years, there has been considerable discussion concerning the terms used to describe the colours and also the understanding of attributes relationship that require consideration for full description of colour appearance. In the scope of the title of this paper, the relationship of specific terms that describe the intensity of colour; brightness, brilliance, lightness, saturation and luminance, will be discussed in terms of achromatic white and the property of whiteness and magenta as well, being both specific for their characteristics of brightness, brilliance and luminance.

White is the achromatic colour characterized by the maximal reflectance of incident light on high level of lightness, having a very low colour saturation and low portion of dominant hue. It is the colour of high brilliance, brightness and luminance. In three dimensional colour space, whites are placed in an area near to the top of the central achromatic axis of the colour solid[1,2,3]. White surfaces reflects strongly (>>50%) throughout the spectrum and the higher and more uniform that spectral reflectance is, the whiter is the appearance of the surface. Since there is no absolute white surface, it can be said that the white is a colour as any chromatic colour and can be objectively measured and determined in terms of whiteness and in terms of colorimetric parameters. The usage of fluorescent whitening agents (FWA) or optical brightening agents (OBA) enhanced the whiteness by obtaining an outstanding brightness, but this kind of whiteness is moved away from the achromatic point towards the spectrum of a blue colour of dominant wavelength of 470 nm[1]. In this paper, only small part of the significant scientific – research work in the scope of whiteness and fluorescence will be presented as the contribution to global discussion and understanding of importance of brightness, lightness, brilliance and saturation relationship in colour appearance[1,2,3].

Also, a part of the experimental work in the field of chromatic colours will be presented on the example of one specific chromatic colour, characterised with unique relationship of brightness, brilliance, saturation and luminance – magenta, which does appear in nature but it does not exist in the spectrum. In this paper some spectral aspects of colour magenta in terms of specific radiant energy and given specific wavelength of absorption will be discussed, based on spectrophotometric measurement and spectral data analysis.

THEORY

Although the basic colour theory describes the colour by the attributes of hue, chroma and lightness, Evans proposed in 1974 five basic colour attributes required for full description of colour appearance: brightness, brilliance, lightness, saturation and hue. But it is also important to consider the term luminance, which describing the perceived brightness[1]. Lightness and brightness are both measures of luminance and each hue naturally has an individual luminance value. Brilliance is the state of extreme brightness and encompasses the scale of perception[1,4,5].

In terms of whiteness, its brilliance, brightness and luminance arise from the characteristic of maximal reflectance of incident light on high level of lightness. An absolute white would have the next coordinates corresponding to the chromaticity diagram: (Y, x, y) = (100, x_o, y_o), where (x_o, y_o) are the coordinates of achromatic point for corresponding illuminant, while Y is the measure of luminance. The luminance must not be confused with luminescence. An electronically-excited molecule can lose its energy by emission of radiation which is known as "luminescence". One of these kinds of emission is fluorescence. Fluorescence is an emission process occurring from lowest excited state (S_1) to the ground state (S_0). The frequency of fluorescence radiation is lower than that of excitation light (which is known Stokes Law). For the same compound an ideal emission should be the mirror image of the absorption band system. So, as for the high levels of whiteness achieved by the application of FWAs or OBAs, it is considered to be a new dimension or added value to white accompanied with very high reflectance value in the blue light coming from fluorescence phenomenon clearly presented by Jablonsky diagram for processes involving electronically excited molecule[6,7,8].

Magenta, being chromatic colour, can also be considered from the aspect of specific hue/saturation relationship as well as its natural luminance. Magenta is characterized by high level of saturation at the middle level of lightness, as compared to red and violet hues from the analog spectrums. Also, magenta is having the luminance value 70%, while the colours form analogue spectra – violet has 52% and red has 60%[9]. One very important aspect of observer's psychophysical experience of colour is also the energy associated to polychromatic radiation of a visible spectrum. The definition of light radiation energy arises from the particle – like nature of light, modelled with photons. A photon is a carrier of electromagnetic energy that is dependent upon the wavelength of the light. Since the colour is, by its definition, the phenomena of light, it can be said that every colour from visual light spectrum, regarding the frequency of associated absorption wavelength has its own specific energy[10,11]. So, in this paper, also the specific radiant energy of magenta colour will be discussed and in relation to colour intensity.

EXPERIMENTAL

Chemically bleached plain weave cotton fabric was used for achieving a brilliant white by optical bleaching with stilbene derivate chemical based FWA applied in concentration range (c0 = 0 g/l; c1 = 0,5 g/l; 1 c2 = 5 g/l; c3 = 10 g/l; c4 = 50 g/l) by pad-dry procedure. The fabric spectral characteristics were determined using remission spectrophotometer Spectraflash SF 600 PLUS CT (Datacolor). The relative intensity of fluorescence (Φrel) was calculated from measured fluorescence on adapted spectrophotometer Specol SV (Carl Zeiss). The results of spectral characteristics, whiteness degrees and relative intensity of fluorescence is shown in Table 1. The results of CIE colour coordinates and colour parameters values of measured samples are shown in Table 2. Remission spectra of FWA treated cotton fabrics, defined for illuminant D_{65}, is shown on Figure 1. The experimental part considering the spectral analyses of specific magenta colour was performed on sample selected from the computer data base of spectrophotometric measurement performed in the region of hues from h = 300º to h = 355º. The results are shown in Table 3, in a form of CIELAB colour parameters and colour coordinates values, maximum absorption value with related wavelength (λ) and radiant energy (E). The specific radiant energy was calculated by the equation $E=h\nu$. The remission spectra of analyzed magenta colour and green colour complementary to chosen magenta, is shown on Figure 2, in a form of remission curves diagram.

RESULTS AND DISCUSSION

The results of the highest whiteness degree reached by using 0,5g/L FWA are presented in Table 1. Based on Berger, Hunter and CIE (WI-B, WI-H, WI-CIE) principle of calculation whiteness degrees by including UV stimulation, very high values are obtained by contribution of blue reflectance. In Tab. 1 it can be seen the high Lightness (L*) values are already reached by chemical bleaching. But, FWA builts the basis on which whiteness can be increased by changes in intensity of blue remission spectrum.

As fluorescence is bluish, the yellow/blue coordinate (b*) results in the more blue (-b*) and less red (+a*). Chroma (C*) shows the positive growth as material is more coloured with FWA having more blue saturation (Tab 2).

Table 1. The whiteness degrees, spectral characteristics and relative intensity of fluorescence of optical bleached cotton fabrics

Samples	cFWA [g/l]	W_{Berger}	W_{Taube}	W_{Hunter}	$W_{Stensby}$	W_{CIE}	Φ_{rel}	Rmax [%]	λmax [nm]
c0	0	61,0	57,9	77,6	76,0	61,7	0	89,99	700
c1	0,5	118,1	126,2	114,6	129.4	122,2	31.0	104,46	440

By this changes batochromic shift to the blue-green colour occurred. The changes in *h** values indicates that fluorescent samples, in compare to the untreated material, move from yellow to blue-violet part of the spectrum (Tab 2).

Table 2. CIE coordinates of bleached cotton fabrics

Samples	L*	a*	b*	C*	h*
c0	94,14	-0,33	3,19	5,45	95,28
c1	94, 0	2,51-	-9.14	9,49	288,57

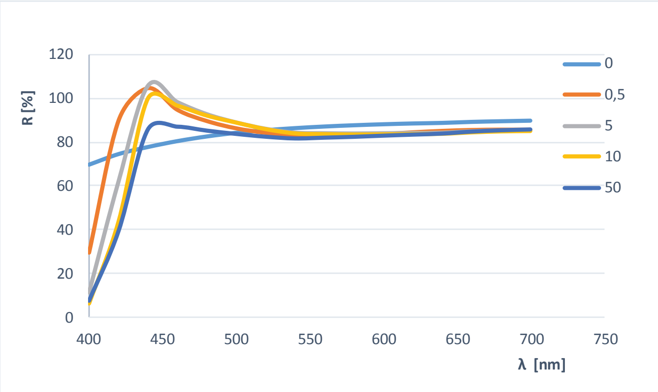

Figure 1: Remission spectra of FWA treated cotton fabrics under illuminant D65

By chemical bleaching of cotton fabric reflectance never reach 100% but when FWA is present these values overcome 100% of the reflectance values. This high energy of bluish light contributes to the brilliance of white surfaces (Figure 1).

The relationship of chroma and hue for chromatic colours is very complex and the visual experience of this relationship will depend on degree of colour purity as well as the lightness level at which a particular hue reaches its maximal saturation. This particular relationship for magenta colour, showed in Table 3, confirms the specific nature of magenta being the colour of high natural luminance, brightness and brilliance, since, in relation to other colours from analogue spectra (red and violet), achieve higher level of chroma (C*>50) on, approximately middle level of lightness (40 < L*< 60). For red and violet spectra, which are analogue to magenta, the maximal chroma C* values are in the range of 40 to 50 (expressed in CIE units), for the middle levels of lightness (L* ≈ 50 expressed in CIE units).

Table 3. CIE coordinates, characteristic minimum of remission value with corresponding wavelength and specific radiant energy calculated for magenta and complementary green colours

	L*	a*	b*	C*	h	R (min)	λ min (nm)	E
Magenta	45,62	56,08	-9,38	56,86	350,5	3,55	560	$3{,}551\text{x}\ 10^{-19}$ J
Green	43,08	-51,48	7,75	52,06	171,44	1,69	640	$3{,}107 \times 10^{-19}$ J

Nevertheless, the objective values presented in Table 3, only partially explain why the magenta is perceived so bright having the luminance value 70%[9]. The explanation of why it is perceived so brightly, is in the physiology of the eye and the process of color perception. According to trichromatic theory of visualization, there are three kinds of cones in human eyes which are sensitive to red, green and blue spectrum. In order to perceive magenta, two sets of cones are excited at once, blue and red[1,4,5]. So, magenta is not one color but two, perceived as red and blue – violet at once. In this process of visualization Red and Blue eye receptors are not just evenly excited, but are excited on high intensity, so this intensity of excitation in blue spectrum contribute to the visual experience of magenta as highly bright and brilliant colour. In magenta there is no green component and in the process of visualization the Green eye receptor stays unexcited. From the spectral aspect, magenta bridging the two ends of a spectrum, and incorporates the red spectrum which is characterized by the lowest frequency of the visible spectrum and medium energy level of the absorption, and blue spectrum, characterized by the highest frequency of the spectrum and higher energy of absorption compared to red spectrum.

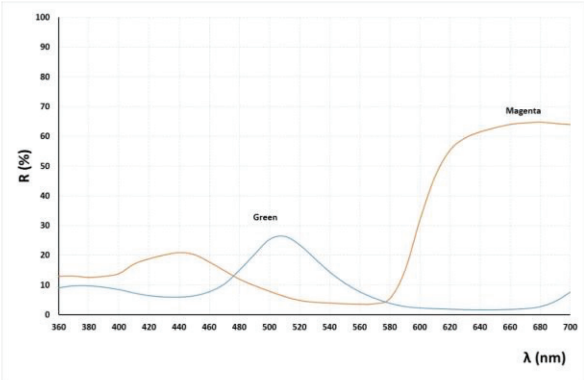

Figure 2. Remission spectra of magenta and complementary green colour under illuminant D65

Therefore, specific energy of Magenta, combines two extremes and at given specific wavelength of absorption, which is located in the green spectrum, is characterized by a medium level of specific energy. The magenta is complementary to green colour of a hue value (h=175º-170º), that has corresponding maximal chroma to magenta, on the similar level of lihgtness. It can be said that it is a complementary pair of colours with corresponding intensity and specific energy (Tab 3). However, the characteristic of a specific colour energy should not be considered separately from the colour intensity. The specific colour energy will not change with the change of chroma and lightness.

The colour intensity, however, will depend on the specific lightness and chroma ratio. Therefore the visual experience of an observer will be the result of interaction between the specific colour energy and its intensity.

CONCLUSION

White coloured textile material with high bluish fluorescence contributes to the high whiteness and a beauty in the optimal range of FWA concentration. This gives "the most brilliant white". From the psychological point of view this is important phenomenon for the further research.

It has been showed that magenta can be considered as the colour obtaining higher luminance that natural luminance is. For magenta it is characterized by high value of saturation at the middle level of lightness, as compared to red and violet hues from the analog spectrums.

REFERENCES

[1] Kumar, A.; Choudhury, R.: *Principles of Colour Appearance and Measurement, Volume 1: Object Appearance, colour perception and instrumental measurement*, Woodhead Publishing, Cambridge, UK, 2012., ISBN 978-0-85709-229-8

[2] Puebla, C. : *Whiteness Assessment: A Primer*; Axiphos GmbH, Germany, Sept. 2006

[3] Brown, A.: Colour harmony in challenge", *Color Research and Application* 34 (6), 1235-1241, 2009

[4] Wyszecki, G; Stiles, W.S.: *Colour Science: Concepts and Methods, Quantitaive Data and Formulae,* 2nd Edn., John Wiley and Sons, 1982., New York, USA, ISBN 978-0-471-39918-6

[5] McDonald, R.: Colour Physics for Industry, Society of Dyers and Colourists Edt., (1987.), England, ISBN 0 901956 45 7

[6] Ranby, B. Rabek, J. F. : Photodegradation, Photo-oxidation and Photostabilization of Polymers, In. B. Ranby and J. F. Rabek, John Wiley, London, New York, Sydney and Toronto, 6-27, 1975

[7] J. Shore: "Fluorescent Brightening Agents", *Colorants and Auxiliaries: Organic Chemistry and Application Properties*; *Vol. 2: Auxiliaries*; Chapter 11; 2nd Edition; In J. Shore. Society of Dyers and Colourists, Bradford, 760-812; 2002

[8] A. M. Grancarić, A. Tarbuk, I. Dumitrescu, J. Bišćan, "UV Protection of Pretreated Cotton – Influence of FWA's Fluorescence", *AATCC Review* 6 (4), 44-48, 2006

[9] http://www.workwithcolor.com/color-luminance-2233.htm; Accessed: 10.7.2017.

[10] OSA: *Handbook of Optics, Volume II: Design, Fabrication and Testing; Sources and Detectors; Radiometry and Photometry*, DeCusatic, K. M. (Eds), Orlando, Florida, USA, 2010., ISBN 978-0-07162927-0

[11] Csele, M.: *Fundamentals of Light Sources and Lasers*; John Wiley and Sons, Hoboken, New Jersey, USA, 2004., ISBN 0-471-47660-9