Effect of fluorescent agents on the permanence of printed materials

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Abstract. The decay of fluorescence on a range of commercially available papers was investigated by exposing them to a 1KW tungsten lamp for a total of 10 hours, with the samples removed for measurement at regular intervals. The results indicated that FWA decay is more rapid on papers with higher FWA efficacy. Only the papers with minimal FWA efficacy reached a plateau after which there was no further significant decay.

1. Introduction

Most commercially available papers have fluorescent whitening agents (FWAs) added to increase brightness and whiteness. FWAs used in papermaking are stilbene molecules that are excited by radiation in the ultra-violet and emit light in the visible region. From a conservation perspective, these FWAs lead to two problems: firstly, the measurement and viewing of such materials is dependent on the UV content of the illumination used; and secondly, permanence is low owing to the tendency of the FWA efficacy to reduce over time, primarily on exposure to UV radiation. These problems are exacerbated by the different illumination sources standardised by the papermaking and printing industries for the measurement of paper and prints, and further by a divergence between the standard daylight viewing conditions used in visual evaluation of papers and prints, and the actual UV content of end use conditions.

ISO 13655 [1] and 3664 [2] (defining graphic arts measurement and viewing respectively) have recently been revised in an attempt to address these problems by requiring stricter conformance with the specified spectral power distribution.

To investigate this problem, a range of commercially available papers were subjected to a 1KW tungsten lamp in a Fadeometer for a total of 10 hours, with the samples removed for measurement at regular intervals.

One issue encountered is that fluorescent efficacy is not well defined. One widely-used method is to calculate the fluorescent component of CIE Whiteness, but this relates to colorimetric rather than spectral quantities. Loeffler and Green [3, 4] recently proposed a spectral method based on summing the differences between a UV included and UV excluded measurement.

Print permanence relates to the appearance of a print with time. The ability of a print to maintain accurate color strength with time due to light exposure and subsequent fading is very important since the demand of printing industry to maintain color precision and print permanence is high. The rate at
which deterioration occurs depends primarily on two main factors: the print itself, that is, the ink and the substrate, and the environmental condition the print is exposed to.

Fluorescent whitening agents (FWAs), also known as optical brightening agent (OBAs), are added to most commercial papers to increase the apparent whiteness or brightness of papers as they absorb ultraviolet radiation and re-emit it in the blue region of the visible spectrum. This can also compensate for a yellow tint of many types of pulps. The derivatives of diaminostilbene sulfonates are used as FWA that are highly conjugated molecules having planar structure and anionic charge. There are different grades of FWA, but papermakers prefer tetrasulfonated stilbene as it has intermediate solubility in water and it is readily retained on fibers, especially if alum or another cationic material is present.

2. Fluorescent efficacy and fading

In this study,

\[ \text{Fluorescent efficacy} = \frac{R - R_{\text{uv cut}}}{R} \]  

(1)

where \( R \) and \( R_{\text{uv cut}} \) are the sum of the spectral reflectance factors of a paper, measured without and with a UVcut filter respectively.

Fading (at a particular time interval) is defined as follows:

\[ \text{Fading} = \frac{R - R_t}{R} \]  

(2)

where

- \( R \) = Sum of initial spectral reflectance factors without UV cut filter at time \( t=0 \), and:
- \( R_t \) = Sum of spectral reflectance factors without UV cut filter at time \( t \)

3. Experiment

A range of commercially available papers was used in this study. The fluorescent whitening agent (FWA) content of the papers were measured according to equation (1). The instruments used for this purpose were a Gretag-Macbeth Spectrolino and a Datacolor Spectraflash. The spectral reflectances were measured with and without a UVcut filter. The (initial) FWA content of the different papers is given in Table 1.

| Paper grade | FWA content |
|-------------|-------------|
|             | 0.011       |
| 2           | 0.006       |
| 3           | 0.053       |
| 4           | 0.103       |
| 5           | 0.089       |
| 6           | 0.040       |
| 7           | 0.004       |

The paper samples were placed inside a Fadeometer and exposed to a 1KW tungsten lamp for a total of 10 hours, with the samples removed for measurement at regular intervals. The Fadeometer has water cooling but does not have control of humidity or temperature.
5. Result and Discussion

The different types of papers in this study have different levels of fluorescent whitening agents. The fluorescent efficacy of papers were defined as described by Loeffler and Green [3, 4].

The results of fading of the different papers is given in Figures 1-5.
Figure 3: Rate of fading of paper no.3

Figure 4: Rate of fading of paper no. 4
It can be observed that the degree of fading depends on the FWA content of paper, and that the rate of fading is almost negligible for papers having little FWA content. The degree of fading against time for different types of papers is plotted, and it can be observed that the extent of fading varies with time in a power series with a negative coefficient. The rate of fading is initially high and decreases with time.

The power series coefficients of rate of fading are shown against the FWA content in figure 6. A linear correlation ($R^2 = 0.8577$) indicates that the rate of fading rises with increasing FWA content.

References

[1] ISO 13655:2009 Graphic technology and photography — Spectral measurement and colorimetric computation for graphic arts images, ISO, Geneva

[2] ISO 3664:2009 Graphic technology and photography — Viewing conditions, ISO, Geneva

[3] Loeffler E and Green P J 2008 Estimating the Spectral Reflectance of Fluorescent Offset Papers for Varying Illuminants Proc. IARIGAI 2008

[4] Loeffler E and Green P J 2008 Scalable Model Spectra Enabling Estimation of Fluorescence Characteristics of Brightened Offset Papers Under Different Illuminants Proc ISCC Special Topics Meeting 2008