

FLUORESCENT DISPERSE DYES: REFLECTANCE SPECTRA, RELATIVE STRENGTH AND PERFORMANCE EVALUATION OF COUMARIN CLASS ON POLYESTER/COTTON BLENDED FABRIC

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Abstract

This study attempted to focus on some important properties of regular fluorescent disperse dyes on polyester/cotton fabric. A 60/40 p/c blended woven fabric was used to dye only the polyester part in pad-thermosol dyeing process (continuous method) with different concentrations of fluorescent disperse dyes. The selected dyestuff was Terasil Flavine 10GFF belonging to coumarin class of fluorescent dye. This paper mainly aims to investigate Spectral parameters such as Reflectance curve, K/S values (with Kubelka-Munk equation) and Relative strength percentage with different concentrations of fluorescent dyes. Different color fastness properties like wash, water, rubbing, perspiration and light fastness were also assessed to evaluate performance of polyester substrate dyed with fluorescent dyes.

Keywords: Fluorescence, disperse dye, pad-thermosol dyeing, reflectance, k/s value, relative strength, color fastness.

1. INTRODUCTION

The applications of fluorescent textiles are associated with their ability to attract attention, because of the remarkable vivid brilliance of the colors which results from the extra glow of emitted fluorescent light [1].

Fluorescent fabrics may be used for specific aesthetic and fashion purposes, the eye-catching bright colors providing unique creative opportunities for the textile and garment designer. They are also used for functional reasons, assuming special importance in leisurewear, sportswear and work wear. Police, firefighters and other emergency services personnel, and construction workers who require visibility in their work surroundings wear garments with fluorescent colors [2].

Fluorescent dyes have been defined as compounds which both absorb and also emit strongly in the visible region of the electromagnetic spectrum, and which owe their potentials application to their intense fluorescence properties [3].

Fluorescent dyes are of much greater importance for application to synthetic fibers such as polyester, polyamides and polyacrylonitrile, sometimes also in conjunction with elastane fibers. The most important textile applications are on polyester and thus the most important fluorescent textile dyes are from the disperse dye class. [2]

An interesting publication analyses the market for fluorescent dyes in Poland and assesses the suitability of the commercially available yellow dyes to meet the requirements of the European standard (EN 471:1997) for high visibility 'warning' clothing [4].

Fluorescent dyes to be of practical use must produce a pure color dictated by their absorption and emission spectra [5]. The absorption and emission spectra of a fluorescent dye often approximate to mirror images of one another as illustrated in Fig 1 [2]. The difference between the absorption and emission wavelength maxima is referred to as the *Stokes shift* (described by Sir Jorge Gabriel Stokes).

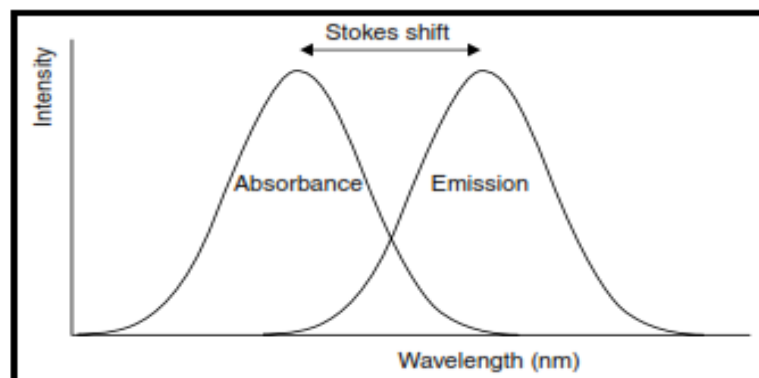


Fig.1 Absorption and emission spectra of a typical yellow fluorescent dye

Coumarin derivatives provide the most important industrial fluorescent dyes. Fluorescent coumarins are known which absorb and emit in most parts of the visible spectrum, although most commercial products are yellow with a green fluorescence. This group provides important disperse dyes which allow synthetic fibers, especially polyester, to be dyed in brilliant fluorescent greenish–yellow shades. [2]

A general structure of coumarin class of fluorescent dye of commercial importance is given in the Fig-2 [1].

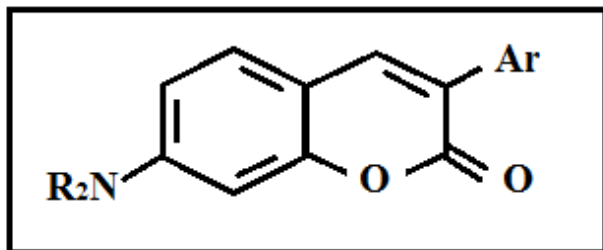


Fig 2: Coumarin class of Fluorescent dye

This paper mainly focuses on the study of some spectral properties specifically relative strength of dyes with reflectance and k/s values with varying dye concentrations (shade percentage) of fluorescent disperse dye of coumarin class. The commercial fluorescent dyes recommended for textiles are often criticized for light fastness properties which are unable to meet the standards required by more demanding applications. This paper also aims to evaluate different color fastness properties such as wash, water, perspiration, rubbing including light fastness of coumarin class of dyes.

2. MATERIAL & METHODS

2.1 Material (Fabric)

Woven desized, scoured and bleached P/C fabrics were used for this experiment to dye (only the polyester part) in pad-thermosol dyeing process (continuous method) with different concentrations in gram per liter (gpl) of fluorescent disperse dye. The specifications of fabrics are given in Table 1.

Table:1 Fabric specifications

Parameters	Desized-Scoured-Bleached Fabric
Structure	Woven (poplin)
Composition	Polyester/Cotton blended
Blend percentage	60/40
Ends/inch	110
Picks/inch	73
Warp count	45
Weft count	45
GSM	95

2.2 Method

2.2.1 Dyeing Procedure (Pad-Dry-Thermosol Method)

Terasil Flavine 10 GFF fluorescent disperse dye (Huntsman) was collected from swiss colour, Bangladesh. Pad-thermosol dyeing [7] procedure was adopted to dye the fabric samples. 8 pieces of pretreated blended p/c samples were padded in the dye bath using laboratory padding mangle of each concentration separately for both classes of dyes. After padding the samples were dried thoroughly and cured in the laboratory dryer. The dye bath set-up, drying and curing conditions are given in Table 2

Table: 2 Dyeing parameters

Fluorescent dye (disperse)	Terasil Flavine 10 GFF
Chemical class	coumarin
Dye concentrations, gpl	1, 3, 5, 10, 20, 30, 40, 50
Dispersing agent, gpl	2
Sequestering agent, gpl	1
Anti-migrant, gpl	20
Acetic acid, gpl	0.5
pH	5.5
Wet pick-up %	60
Drying temperature, °C	130
Drying time, sec	120
Curing temperature, °C	220
Curing time, sec	90

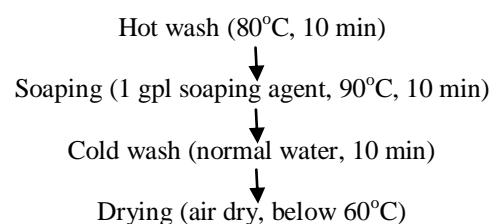
2.2.2 After-Treatments

Reduction cleaning [8] was done manually after curing for every samples taking in a beaker separately with 500 ml solutions with the chemicals and parameters listed in table 3.

Table 3: Reduction cleaning

Alkali (Caustic soda, NaOH), gpl	2
Hydros (Sodium hydro Sulphite, Na2S2O4), gpl	2
Liquor temperature, °C	70
Treatment time, min	20

Then all of the samples were treated according to the flow chart-



2.2.3 Spectral Measurement Procedure

Reflectance values and curves of the dyed fabrics were determined in the visible portion of the spectrum (400-700 nm) using a reflectance spectrophotometer (Datacolor 650) and the standard illuminant was D65 with 10° observer. The measurements were taken in four different places making four folds of each samples and their average was taken for the analysis of each result. K/S values of the minimum reflectance value were obtained using the Kubelka-Munk equation [9]:

$$K/S=(1-R)^2/2R$$

K/S= absorption function

R= minimum reflectance value at a wavelength of maximum absorption

The color strength values (%) of samples were determined in comparison to the deepest dyeing (50 gpl dyed sample) as 100% color strength by using the following equation:

$$\% \text{ Strength} = \frac{K/S(\text{sample})}{K/S(\text{standard})} \times 100$$

2.2.4 Evaluation of Color Fastness of Dyed Samples

Different color fastness properties of the dyed samples were assessed according to the following methods:

- Color fastness to wash (ISO 105 C06) [10]
- Color fastness to water (ISO 105 E01) [11]
- Color fastness to perspiration (ISO 105 E04) [12]
- Color fastness to rubbing (ISO 105 X12) [13]
- Color fastness to light (mercury vapour lamp, 72 hrs)

Color fastness (wash, water, perspiration, rubbing) were assessed using Grey Scale on a rating of 1 to 5 where (rating 5 & 1 describe *excellent* and *very poor* respectively) and light fastness was evaluated using Blue Wool Standard Scale on a rating of 1 to 8 whereas (rating 8 & 1 describe *outstanding* and *very poor* respectively).

3. RESULTS & DISCUSSION

3.1 Spectral Data Analysis

3.1.1 Reflectance Data in the Visible Spectra

Table-4: Spectral value of Terasil Flavine 10 GFF

Dye Conc. gpl	R% min (approx)	K/S=(1-R) ² /2R	Relative Strength%
1	25.39	1.1	22.6
3	20.85	1.5	30.9
5	18.5	1.8	37
10	14.45	2.53	52.1
20	11.2	3.52	72.5
30	9.8	4.15	85.5
40	9	4.6	94.7
50	8.6	4.86	100

Table 4 represents the reflectance percentage (%R) of Terasil Red 3BFF dyes of different concentrations at every 10 nm intervals of wavelength over the visible region (400-700nm). The wavelength of minimum and maximum reflectance were observed at 440 nm and 510 nm respectively.

Table.5 % Reflectance of Terasil Flavine 10GFF on visible spectrum

λ nm	% Reflectance							
	1 gpl	3 gpl	5 gpl	10 gpl	20 gpl	30 gpl	40 gpl	50 gpl
400	33.2	29.6	23.3	17.8	16.1	15.5	13.0	11.7
410	31.1	25.7	21.4	17.0	14.4	14.1	12.5	11.0
420	27.7	23.5	20.8	16.0	13.4	12.4	11.4	10.0
430	25.5	21.7	19.8	15.2	12.3	10.3	10.2	8.5
440	25.4	20.9	18.5	14.5	11.2	9.8	9.0	8.6

450	24.8	21.6	18.2	15.1	12.0	10.0	9.2	8.5
460	27.8	23.0	19.8	17.4	12.6	10.6	9.8	9.2
470	32.7	28.4	20.2	19.8	14.0	12.4	10.2	11.2
480	54.2	38.0	26.5	26.7	18.7	14.5	13.1	13.1
490	85.7	70.6	52.3	41.0	30.5	28.8	22.4	21.7
500	118.3	117.4	98.6	83.1	50.3	47.0	45.8	44.3
510	125.8	126.0	126.6	122.4	121.4	120.9	122.0	125.0
520	122.1	125.2	128.4	134.0	138.1	139.9	140.5	142.5
530	114.4	120.3	126.7	130.1	133.0	135.1	137.0	139.8
540	106.2	111.1	119.1	118.0	119.4	121.8	124.0	129.8
550	100.5	105.4	110.4	109.4	112.0	116.0	115.0	117.3
560	95.6	98.3	102.8	103.0	105.2	107.2	108.0	109.6
570	92.1	94.1	97.5	99.7	100.8	102.3	103.8	105.2
580	89.5	91.0	93.4	96.2	97.4	98.1	99.0	101.8
590	87.4	88.7	90.1	92.7	93.8	94.4	96.3	98.7
600	86.2	87.5	88.3	90.8	91.6	92.9	93.8	95.8
610	85.5	86.1	86.9	89.2	89.8	90.2	92.0	93.1
620	85.1	85.5	85.8	87.7	88.1	89.5	90.0	91.4
630	85.3	85.4	85.7	87.5	87.6	88.2	88.8	89.1
640	85.6	85.6	85.6	87.3	87.4	87.5	88.1	88.8
650	85.8	85.6	85.6	86.9	86.7	86.8	87.0	88.7
660	86.1	85.9	85.7	87.1	86.4	86.4	87.1	87.5
670	86.3	86.1	85.9	86.9	86.6	86.4	86.4	87.5
680	86.4	85.6	85.9	86.9	86.3	86.4	86.4	86.4
690	86.4	86.2	85.9	86.8	86.6	86.2	86.4	86.4
700	86.6	87.0	86.2	86.9	86.4	86.3	86.4	87.4

Table 5 represents the reflectance percentage of Terasil Flavine 10 GFF dyes of different concentrations at every 10 nm intervals of wavelength over the visible region (400-700nm).

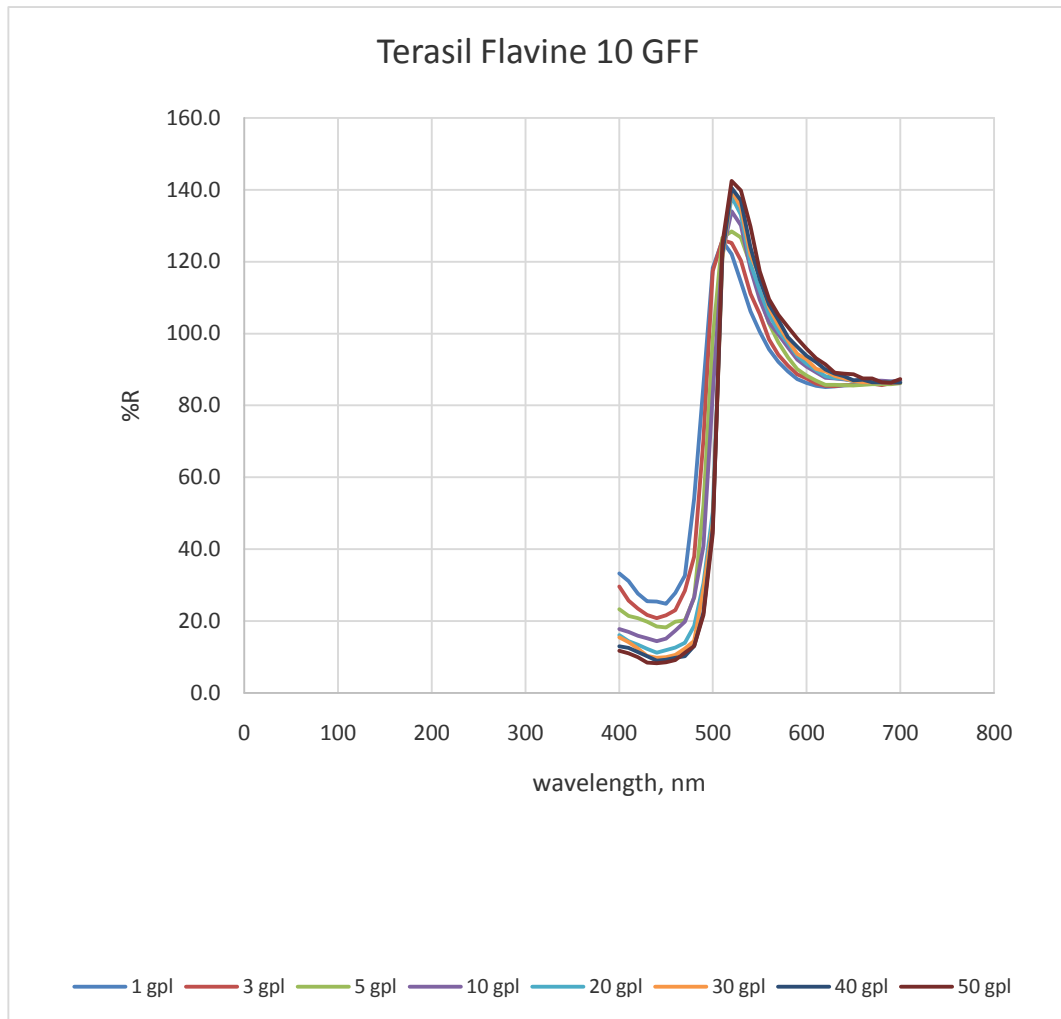


Fig.3 Reflectance curve of Terasil Flavine 10 GFF

The wavelength of minimum and maximum reflectance were 10-28% and 122-142% observed at 440 nm and 520 nm respectively throughout the concentrations of fluorescent dyes. A reflectance curve was also constructed with wavelength with all concentrations of dyes showing in fig.3.

3.2 Color Fastness Evaluation

Table 6: Color Fastness to wash

Dye conc gpl	color change	staining					
		AC	CO	NL	PES	AR	WL
1	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3	4-5	4-5	4-5	4	4-5	4-5	4-5
5	4-5	4-5	4-5	3-4	4-5	4-5	4-5
10	4-5	4	4-5	3	4-5	4-5	4-5
20	4-5	4	4-5	3	4-5	4-5	4-5
30	4-5	3-4	4	2-3	4	4-5	4-5
40	4	3	4	2-3	4	4	4
50	4	3	4	2	4	4	4

Table 6 -10 illustrate the grades color fastness to wash, water, perspiration, rubbing and light fastness respectively. AC(acetate), CO (cotton), NL (nylon), PES (polyester), AR (acrylic),WL (wool) staining were assessed with DW multifibre fabric.

Table-7: Color Fastness to Water

Dye conc. gpl	color change	staining					
		AC	CO	NL	PES	AR	WL
1	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3	4-5	4-5	4-5	4	4-5	4-5	4-5
5	4-5	4	4-5	3-4	4-5	4-5	4-5
10	4-5	4	4	3	4-5	4-5	4-5
20	4-5	3-4	4	3	4	4-5	4
30	4-5	3-4	4	2-3	4	4-5	4
40	4	3	3-4	2	3-4	4	3-4
50	4	3	3-4	2	3	4	3-4

Table-8a: Color Fastness to Acid Perspiration

Dye conc. gpl	color change	staining (acid)					
		AC	CO	NL	PES	AR	WL
1	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3	4-5	4-5	4-5	4	4-5	4-5	4-5
5	4-5	4-5	4-5	3-4	4-5	4-5	4-5
10	4-5	4	4-5	3	4-5	4-5	4-5
20	4-5	4	4	3	4-5	4-5	4-5
30	4	3-4	4	2-3	4	4	4-5
40	4	3-4	3-4	2-3	4	4	4
50	4	3	3-4	2	3-4	4	4

Table-8b: Color Fastness to Alkali Perspiration

Dye conc. gpl	color change	staining (alkali)					
		AC	CO	NL	PES	AR	WL
1	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3	4-5	4-5	4-5	4-5	4-5	4-5	4-5
5	4-5	4-5	4-5	4	4-5	4-5	4-5
10	4-5	4	4-5	4	4-5	4-5	4-5
20	4-5	4	4-5	3-4	4	4	4-5
30	4	3-4	4	3-4	4	4	4
40	4	3	3-4	3	3-4	4	4
50	4	3	3-4	3	3-4	4	4

No remarkable change found after wash for all the classes of dyes, poor staining rating to nylon was noticed for higher concentrations of dyes otherwise slight staining was found for other concentrations (Table-6). Change in color after water treatment showed good fastness rating throughout all concentrations for dyes, poor nylon staining was found with higher concentration otherwise moderate to good (Table-7).

Slight change in depth were found for overall dye concentrations in both Acid & Alkali medium, The dye stained in acid more than in alkali to acetate, cotton, acrylic specially nylon with highest concentrations used (Table-8).

Table-9: Color Fastness to Rubbing

Dye conc. gpl	color change	staining	
		dry	wet
1	4-5	4-5	4-5
3	4-5	4-5	4
5	4-5	4-5	4
10	4-5	4-5	4
20	4-5	4	3-4
30	4-5	4	3-4
40	4	4	3
50	4	4	3

The results of rubbing test indicated overall strong staining in dry state and moderate staining resulted in wet rubbing (Table-9). The light fastness exceptionally resulted in strong fading with increasing concentrations (for dark shades) whereas light concentrations exhibited good photo stability (Table-10).

Table-10: Color Fastness to Light

Dye conc. gpl	Fading
1	7
3	6
5	6
10	5
20	5
30	4
40	3
50	3

4. CONCLUSION

Accurate characterisation of a fluorescent surface requires a bispectral instrument with two monochromators [14] but this spectral measurements were performed with traditional spectrophotometer which was available in industrial dyeing laboratory. Hence The results may vary slightly from the actual. The minimum and maximum reflectance of the luminous yellow shade was found in 440nm and 520 nm respectively from the emission spectra. Maximum absorption value was considered for minimum reflection from reflection spectra only as absorption spectra was not constructed. There was a sharp increase in strength with increasing concentrations of dye up to 30 gpl dye concentration indicating 85% as compared to that incase of 50 gpl. Strong color fastness resulted for wash, water and perspiration but poor nylon staining was caused in every case for higher concentrations. Both dry and wet rubbing was good enough. Exceptional results for light fastness indicated significant fading in case of darker shades which was unusual to regular textile dyes behavior.

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BIOGRAPHY



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