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Dichroism measurements in forensic fibre examination Part 1 — Dyed polyester fibres

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ABSTRACT

One hundred and twenty dyed polyester samples were examined with plane polarized light on their dichroic behaviour by optical light microscopy (OLM) and microspectrophotometry in the visible range (MSP Vis). It was found that most of these disperse dyed polyester fibres possess a strong dichroism, which fall into two broad categories. Either a decrease of intensity (hypochromic effect) or a change of hue (hypsochromic or bathochromic shift of absorption bands) is noted. These dichroic effects are related to the orientation of the dye structure with respect to the polymer chains.

1. Introduction

Forensic scientists are constantly seeking examination methods that are non-destructive, that are fast in obtaining analysis results and that have a high discrimination power. Optical microscopy and spectroscopic methods are commonly used in forensic fibre examinations. Polarization microscopy is a well established method that allows one to obtain information about the chemical fibre composition simply by observing interference colors. Associated with this method, but fundamentally different, is the observation and measurement of dichroism, which is a well studied method in the field of oriented systems [1,2]. The use of a single polarizer oriented along with or perpendicular to the fibre axis allows one to observe or measure any differences in fibre color when plane polarized light of the two main directions is used. The linear dichroism (LD) spectrum is obtained by subtraction of the absorptions in parallel and perpendicular positions for each of the corresponding wavelengths in the two spectra:

$$LD(\lambda) = A_{para}(\lambda) - A_{perp}(\lambda)$$

For those spectral regions where more light is absorbed when the direction of polarization is parallel to the fibre axis, the resulting part of the LD spectrum will be positive. For other spectral regions where more light is absorbed when the polarization direction is perpendicular to the fibre axis, the resultant LD spectrum will be negative.

The dichroic ratio (or polarization ratio) of a given absorption band is the quotient of the absorptions in parallel and perpendicular positions:

$$R(\lambda) = A_{para}(\lambda) / A_{perp}(\lambda)$$

This parameter reflects the strength of the intensity decrease (hypochromic effect; $R > 1$) or increase (hyperchromic effect; $R < 1$) when using respectively plane polarized light parallel and perpendicular to the fibre axis.

A change in hue should be reflected in the absorption spectrum. The band of highest intensity can shift to either lower wavelengths (hypsochromic shift or blue shift, $\Delta\lambda_{max} > 0$) or to higher wavelengths (bathochromic shift or red shift, $\Delta\lambda_{max} < 0$) where

$$\Delta\lambda_{max} = \lambda_{max}(para) - \lambda_{max}(perp)$$

We believe that the observation of dichroism with optical light microscopy (OLM) and its measurement with microspectrophotometry (MSP) is not systematically exploited in most forensic fibre laboratories and that information on this topic is very rare [3,4]. This is rather surprising because both methods are of such high simplicity

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Table 1
Dye systems of the polyester samples, their dichroic features as observed with microscopy and their spectral characteristics (MSP-PPL).

Sample	Ref. FRC	Commercial dye name	Chemical dye class	CI generic name (const. number)	Fibre color	Microscopy	MSP-PPL
PES1	11488	Undyed Perylene sample	/		/	Weak (grey>translucent)	
PES2	11489	Duranol Brilliant Yellow 6 G (8%)	Anthraquinoid	Disperse Yellow 13 (CI 58900)	Yellow	Weak	R = 2.3
PES3	11490	Dispersol Fast Yellow G (5%)	Azo monoazo	Disperse Yellow 3 (CI 11855)	Bright yellow	Weak	R = 1.9, Δλ = +20 nm
PES4	11491	Dispersol Fast Yellow GR (7%)			Yellow	No	R = 1.3
PES5	11492	Dispersol Fast Yellow A (10%)	Nitro	Disperse Yellow 1 (CI 10345)	Yellow	No	R = 1.2, Δλ = +15 nm
PES6	11493	Dispersol Fast Orange B (6%)	Azo/monoazo	Disperse Yellow 97 (CI 12055)	Orange	Strong (orange>orange–yellow)	R = 1.6, Δλ = +15 nm
PES7	11494	Duranol Orange G (10%)	Anthraquinone	Disperse Orange 11 (CI 60700)	Orange	Strong	R = 1.7, Δλ = +5 nm
PES8	11495	Dispersol Fast Orange G (7%)			Orange	Strong (orange>orange–yellow)	R = 1.2, Δλ = +60 nm
PES9	11496	Dispersol Fast Orange A (6%)	Azo/monoazo	Disperse Orange 1 (CI 11080)	Orange	Strong	R = 2.2, Δλ = +10 nm
PES10	11497	Dispersol Fast Orange Brown RN (7%)	Azo/monoazo	Disperse Orange 5 (CI 11100)	Orange–brown	Strong (red>orange)	R = 1.2, Δλ = +60 nm
PES11	11498	Dispersol Fast Scarlet B (4%)	Azo/monoazo	Disperse Red 1 (CI 11110)	Pale orange	Strong	R = 1.9
PES12	11499	Duranol Red GN (10%)	Anthraquinone	Disperse Red 9 (CI 60505)	Pink	Strong (red>pink)	R = 1.6
PES13	11500	Dispersol Fast Crimson B (3%)	Azo/monoazo	Disperse Red 13 (CI 11115)	Pink	Strong (violet–red>pink)	R = 2.4
PES14	11501	Duranol Red 2B (10%)	Anthraquinone	Disperse Red 15 (CI 60710)	Purple	Strong	R = 2.0
PES15	11502	Duranol Red X3B (15%)	Anthraquinone	Disperse Red 11 (CI 62015)	Purple	Strong	R = 1.8
PES16	11503	Duranol Violet 2R (6%)	Anthraquinone	Disperse Violet 1 (CI 61100)	Violet	Strong	R = 2.0
PES17	11504	Duranol Violet RN (7.5%)			Violet	Strong	R = 2.0
PES18	11505	Duranol Violet RN (30%)			Violet	Strong	R = 1.6
PES19	11506	Duranol Brilliant Violet BR (6%)	Anthraquinone	Disperse Violet 8 (CI 62030)	Pale violet	Weak	R = 1.5
PES20	11507	Duranol Blue G (6%)			Weak blue	Strong (green–blue>blue)	R = 2.1
PES21	11508	Duranol Blue GN (6%)			Pale blue	Strong (green–blue>blue)	R = 1.8
PES22	11509	Duranol Brilliant Blue CB (6%)	Anthraquinone	Disperse Blue 1 (CI 64500)	Pale blue	Weak	R = 1.7
PES23	11510	Duranol Brilliant Blue CB (24%)	Anthraquinone	Disperse Blue 1 (CI 64500)	Pale blue	Weak	R = 1.8
PES24	11511	Duranol Blue 2 G (8%)			Pale blue	No	R = 1.6
PES25	11512	Duranol Blue Green B (8%)	Anthraquinone	Disperse Blue 7 (CI 62500)	Pale blue	Weak	R = 1.4
PES26	11513	Duranol Dark Blue TG (7.5%)			Pale blue	Strong	R = 2.0
PES27	11514	Duranol Dark Blue TG (15%)			Blue	Strong	R = 1.9
PES28	11515	Duranol Grey TN (2.5%)			Grey	Strong	R = 2.6
PES29	11516	Duranol Grey TN (10%)			Dark grey	Strong (khaki>grey)	R = 3.0; 2.0
PES30	11517	Dispersol Diazo Black 2B, 5% + Brenthol BT, 4.5%	Developed azo		Brown–orange	Strong (orange–brown>orange)	R = 1.4; 1.7, Δλ = +20 nm
PES31	11518	Brentamine Fast Red GG Base, 6% + Brentosyn BB, 6%	Developed azo		Bright red	No	R = 1.2
PES32	11519	Brentamine Fast Red 3GL Base, 6% + Brentosyn BB, 6%	Developed azo		Bright pink	No	R = 1.4
PES33	11520	Brentamine Fast Red GL Base, 6% + Brentosyn BB, 6%	Developed azo		Bright red	No	R = 1.2
PES34	11521	Brentamine Fast Red B Base, 6% + Brentosyn BB, 6%	Developed azo		Fuchsia	Weak	R = 1.2
PES35	11522	Dispersol Fast Orange G, 6% + Brensosyn BB, 6%	Developed azo		Fuchsia	Strong (deep red>fuchsia)	R = 1.3, Δλ = +20 nm
PES36	11523	Brentamine Fast Blue B Base, 4% + Brentosyn BB, 6%	Developed azo		Blue	Strong	R = 1.3, Δλ = −20 nm
PES37	11524	Brentamine Fast Blue B Base, 3% + Brenthol FO, 3%	Developed azo		Blue	Strong (purple>blue)	R = 1.5, Δλ = −20 nm
PES38	11525	Dispersol Diazo Black 2B, 4% + Brentosyn BB, 6%	Developed azo		Blue	Weak	R = 1.7, Δλ = −10 nm
PES39	11526	Dispersol Diazo Black B, 7.5% + Brentosyn BB, 6%	Developed azo		Blue–grey	Strong (black>blue)	R = 1.2
PES40	11527	Dispersol Diazo Black B, 4% + Brenthol OT, 2.5%	Developed azo		Dark grey	Strong (black>dark violet)	R = 1.2
PES41	11528	Dispersol Fast Orange B (0.8%) + Duranol Red X3B (0.1%) + Duranol Blue G (0.1%)	Ternary dye mixture		Pale yellow	Strong	
PES42	11529	Dispersol Fast Orange B (0.2%) + Duranol Red X3B (0.1%) + Duranol Blue G (0.2%)	Ternary dye mixture		Grey	No	
PES43	11530	Dispersol Fast Orange B (1%) + Duranol Red X3B (0.5%)	Binary dye mixture		Pale orange	Strong	
PES44	11531	Dispersol Fast Orange B (5.1%) + Duranol Red X3B (0.6%) + Duranol Blue G (0.3%)	Ternary dye mixture		Orange	Strong	
PES45	11532	Dispersol Fast Orange B (1.6%) + Duranol Red X3B (2.7%) + Duranol Blue G (1.2%)	Ternary dye mixture		Pale brown	Strong	
PES46	11533	Dispersol Fast Orange B (2%) + Duranol Red X3B (4%) + Duranol Brilliant Violet BR (1%)	Ternary dye mixture		Pale red	Strong (red–brown>pink)	
PES47	11534	Dispersol Fast Yellow A (0.1%) + Duranol Red X3B (0.05%) + Duranol Blue G (0.5%)	Ternary dye mixture		Pale blue	Weak	
PES48	11535	Dispersol Fast Orange B (0.2%) + Duranol Red X3B (0.6%) + Duranol Blue G (8%)	Ternary dye mixture		Blue	Weak	
PES49	11536	Dispersol Fast Yellow A (0.8%) + Duranol Blue G (0.3%)	Binary dye mixture		Grey	Weak	