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Dichroism measurements in forensic fibre examination Part 5—Pigmented fibres

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ABSTRACT

A number of pigmented fibre samples were examined with plane polarized light on their dichroic behaviour by optical light microscopy (OLM) and microspectrophotometry with plane polarized light (MSP-PPL). It was found that about half of the samples show a strong dichroic effect and another 20% have a weak dichroism. Both regular (80%) and inversed dichroic effects (20%) occur. The dichroic characteristics of pigmented fibres can be compared to these of sheet polarizers. It is suggested that the dichroic behaviour of pigmented fibres depends strongly on the crystal structure (shape of the pigment grains) and the draw ratio (orientation of the polymer chains).

1. Introduction

Previous publications have described the occurrence of dichroism for dyed fibres. The most common man-made and natural fibre classes have been explored: polyesters [1], peptidic fibres (polyamides, wool and silk) [2], cellulosic fibres (cotton and viscose) [3] and low birefringent fibres (acrylics and cellulose acetates) [4]. These classes were examined with optical microscopy using plane polarized light (PPL) and their absorption in the visible region was measured using plane polarized light (MSP-PPL). It was found that the dichroism strongly depends on the fibre class, even for fibre classes of similar nature.

This work presents the observation and the measurement of linear dichroism for pigmented fibres. The use of pigments for adding color to the fibre is quite different from the dyeing process. In the textile industry, pigments tend to be water insoluble dyestuffs and these are added to the bulk polymer before spinning the man-made filaments. Pigmented fibres are sometimes designated with terminology such as “solution dyed”, “spun dyed”, “manufacturer dyed” or “dope dyed” fibres. More correctly pigments should be considered as physical inclusions of tiny grains, dispersed between the fibres polymer chains.

The aim of this work is to examine the occurrence of dichroism in pigmented fibres and to compare the dichroic effects found in dyed and pigmented man-made fibres.

2. Experimental

2.1. Samples

Because no manufacturer samples were available to us, the samples were chosen from our fibre reference collection (FRC) and from case work samples.

A list of all 80 pigmented samples is shown in Table 1. The fibre class is given in the third column and was determined using polarization microscopy and FT-IR. Raman spectroscopy was used to confirm the fibre class or to differentiate between sub-classes (for instance for polyamides).

In most samples the chemical composition of the pigments was unknown. Therefore Raman spectroscopy has been used in order to identify some of the pigments. In order to obtain as much information as possible three different laser sources (532, 633 and 785 nm) were used. The information on the pigments is given in the fourth column.[1]

2.2. Microscopy

The samples were examined with microscopy under plane polarized light using the same methodology as the one previously described [1] and the observations are summarized in the last column of Table 1. Samples showing a considerable change in intensity when changing from the parallel to the perpendicular position are described as “strong”. If a clear change in hue was observed, this is described using for instance “strong (green > bluish green)”. Samples

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[1] As FT-IR and Raman were solely used as supporting methods, the measurement conditions are not presented in this publication.

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Table 1
Pigmented fibre samples and their dichroic characteristics as observed with microscopy.

Sample	FRC or case sample no.	Fibre class [a]	Pigment [b]	fibre color (pigment)	Microscopy
PIGM1	FRC1	Ac		Green	No
PIGM2	FRC34	PAN [c]/MA	NI	Red	Strong (deep red > mauve)
PIGM3	FRC60	Modacrylic	Carbon Black	Brownish black	Weak (black > brownish black)
PIGM4	FRC67	Modacrylic		Green	No
PIGM5	FRC68	Modacrylic		Black	No
PIGM6	FRC87	PA 6	NI	Red	Strong (deep red > pink)
PIGM7	FRC124	PP [c]	NI	Pink	Weak (pink > yellowish pink)
PIGM8	FRC126	PP [c]	CuPc	Green	Strong (green > bluish green)
PIGM9	FRC128	PP		Blue	No
PIGM10	FRC147	PES - PET [b]	CuPc	Black	Weak (black > brownish black)
PIGM11	FRC186	CV		Black	No
PIGM12	FRC192	CV	Carbon Black	Black	Weak (black > brownish black)
PIGM13	FRC195	CV	CuPc	Sky blue	Strong (blue > sky blue); negative dichroism
PIGM14	FRC199	PU		Black	No
PIGM15	FRC276	CV	CuPc	Brown	Weak (brown > greenish brown)
PIGM16	FRC280	PAI (Kermel)	CuPc	Yellow-green	Strong (yellow-green > grey green)
PIGM17	FRC333	PES		Black	No
PIGM18	FRC358	PP [c]	Carbon Black	Brownish black	Weak (black > brownish black)
PIGM19	FRC359	PP [c]	Carbon Black	Black	Weak (black > brownish black)
PIGM20	FRC360	PP		Black	No
PIGM21	FRC580	Polyolefine		Blue	No
PIGM22	FRC3928	Polyolefine		Brown	No
PIGM23	FRC3929	PP [c] (fibrillated film)	CuPc	Blue	Strong (greenish blue > blue)
PIGM24	FRC3936	PP (fibrillated film)		Orange	No
PIGM25	FRC3937	Polyolefine		Orange	No
PIGM26	FRC3938	PP [c]	Cl-CuPc	Green	Strong (pale green > green); negative dichroism
PIGM27	FRC3940	PP		Black	No
PIGM28	FRC3945	PET [b]	NI	Pink	Strong (pink > pale pink)
PIGM29	FRC3946	PP [c]	Pigment Red 144	Red	Strong (purple > red)
PIGM30	FRC3948	PP [c]	CuPc	Sky blue	Strong (blue > sky blue)
PIGM31	FRC4056	PAI (Kermel)	Pigment Violet 23	Purple	Strong (dark purple > purple)
PIGM32	FRC4064	PES - PET [b]	Carbon Black	Black	Weak (black > brownish black)
PIGM33	01/01762.5.11 (TEX89B)	CV	Diazo diarylide	Yellow	Strong (orange > yellow)
PIGM34	05/01159.2.60 (TEX89G)	CV	NI	Brown-yellow	Strong (orange > brown)
PIGM35	03/01305.1.2.13 (TEX116B)	PES - PET [b]	CuPc + P. Violet 23	Dull blue	Weak (blue > dull blue); weak negative dichroism
PIGM36	02/05272.1.26 (TEX130)	PAN		Green	No
PIGM37	03/02058.1.14 (TEX140)	PES - PET [b]	NI	Red	Strong (red > pink)
PIGM38	03/02551.1.3.3 (TEX140C)	PES - PET [b]	NI	Red	Strong (red > pink)
PIGM39	03/02551.1.6.5 (TEX140C)	CV	TiO_2 + Pyrazolone (disazo)	Yellow-brown	Weak (yellow > yellow-brown)
PIGM40	95/01681.6.2.24 (TEX148)	CV	NI	Red	Strong (violet-red > red)
PIGM41	03/06621.3.1.4.5 (TEX149)		CuPc	Green	Strong (green > deep green); negative dichroism
PIGM42	04/00167.6.1.29 (TEX150)	PAN		Blue/violet	No
PIGM43	04/01336.15.7 (TEX155)			Blue/violet	No
PIGM44	04/05235.1.1.5 (TEX155C)	PAN		Red/orange	No
PIGM45	04/01426.1.7 (TEX156)	CV	CuPc	Sky blue	Weak
PIGM46	04/04864.2.1 (TEX169)	PP [c]	CuPc	Dull blue	Strong (bluish grey > blue); negative dichroism
PIGM47	06/02552.1.5 (TEX212)	PP [b]	Cl-CuPc + P. Yellow 83	Yellow-brown	Strong (brown > yellow-brown)
PIGM48	06/03109.1.12 (TEX216)	CV	Pigment Red 170	Violet	Strong (violet > red)
PIGM49	06/03109.20.2 (TEX216)		CuPc + P. Violet 23	Dull blue	Strong (grey blue > bright blue)
PIGM50	06/03236.3.39 (TEX216)	CV	P. Red 2 or 10 or 166	Red	Strong (red > orange)
PIGM51	06/03236.2.21 (TEX216)	PES - PET [b]	NI	Dull blue	Strong (blue > grey blue)
PIGM52	06/03236.6.19 (TEX216)	PES - PET [b]	CuPc + P. Violet 23	Purple	Strong (dark purple > blue)
PIGM53	06/03232.2.2.6 (TEX216)			Blue/violet	No
PIGM54	06/03758.1.1.12 (TEX216)			Blue/violet	No
PIGM55	06/03115.1.2.386 (TEX216)	CV	NI	Yellow-green	Weak (grey green > green-yellow)
PIGM56	06/03556.1.3.14 (TEX216)			Green	No
PIGM57	06/05563.1.2 (TEX227)	PE [b] (fibrillated film)	Pigment Red 53	Orange	Strong
PIGM58	07/01722.1.10 (TEX238)	PP [b]	CuPc	Sky blue	Strong (pale blue > sky blue); negative dichroism
PIGM59	07/02595.1.1.1 (TEX248)	PP [c]	Pigment Red 48:3	Orange	Strong (reddish orange > orange)
PIGM60	07/02597.27.1.4 (TEX248)	CV	Pigment Green 47	Green	Strong (pale green > green); negative dichroism
PIGM61	07/02597.27.6.1 (TEX248)	PP [b]	CuPc + P. Violet 37	Grey blue	Weak (grey > grey-blue)
PIGM62	07/02597.27.10.4 (TEX248)			Blue/violet	No
PIGM63	08/00919.1 (TEX251)	PP [c]	Pigment Red 57	Fuchsia red	Strong (purple > red)
PIGM64	07/05586.2.13 (TEX260)	PP [b]	CuPc	Sky blue	Strong (pale blue > sky blue); negative dichroism
PIGM65	08/00165.1.1.1 (TEX265)	CV	CuPc	Sky blue	Strong (pale blue > sky blue); negative dichroism
PIGM66	08/04687.5.2.2 (TEX267C)			Red/orange	No
PIGM67	08/04687.5.2.8 (TEX267C)	PAN [c]	NI	Orange	Weak
PIGM68	08/01201.4.20 (TEX273)			Green	No
PIGM69	08/03414.1.54.1 (TEX281)	PES - PET [b]	CuPc	Green	Strong (green > greenish blue)
PIGM70	09/00581.1.1.1 (TEX300)	PES - PET [b]	NI	Yellowish grey	Strong
PIGM71	09/01432.1.2.1 (TEX302)	PP [c]	CuPc	Blue	Weak (blue-red > blue)
PIGM72	09/00799.1.1.31 (TEX303)			Blue/violet	No
PIGM73	09/00986.8 (TEX304)	PES	NI	Yellow	Strong
PIGM74	09/00987.1.3 (TEX304)	PAN		Yellow	No
PIGM75	09/02247.1.21 (TEX316)	CV	"Reactive Black 5"	Deep blue	Strong