Wilkaan Fong,[1] *B.S.*

Rapid Microscopic Identification of Synthetic Fibers in a Single Liquid Mount

REFERENCE: Fong, W., "**Rapid Microscopic Identification of Synthetic Fibers in a Single Liquid Mount,**" *Journal of Forensic Sciences,* JFSCA, Vol. 27, No. 2, April 1982, pp. 257-263.

ABSTRACT: Most natural fibers are either cellulosic or proteinaceous and can be identified readily by unique morphological features. Synthetic fibers, on the other hand, vary only slightly in shape characteristics. They can, however, because of great compositional differences, be distinguished by their refractive indices, which can often be determined by dispersion staining. A simple scheme is proposed using this technique on fibers mounted in Cargille high-dispersion liquid (index of refraction for 25°C and sodium light equal to 1.525).

KEYWORDS: criminalistics, microscopy, synthetic fibers, refractive index, birefringence

Methods described for the identification of synthetic fibers include those depending on the effects of chemicals and solvents, color tints imparted by identification stains, burn and melt characteristics, infrared absorption spectrum, melting point determined by hot-stage microscopy, density measured by gradient flotation, and refractive index determined through use of a polarizing microscope. All lack one or more of the assets that should characterize identification methods proposed for forensic science use: reliability, applicability to small intermixed samples, nondestructiveness, and rapidity.

Determination of optical properties with a polarizing microscope is a widely used, but inconvenient, technique. The method requires continuous changing of the refractive liquid, which is time-consuming, and is difficult to use on preparations containing a mixture of several fiber types. A method for rapidly identifying a variety of fibers in a single liquid mount is proposed here.

Experimental Procedure

Fibers are mounted on a microscope slide under a coverslip in Cargille high-dispersion refractive index liquid (index of refraction at 25°C = 1.525). The preparation is examined with a polarizing microscope equipped with a 10× dispersion-staining objective. The principles of operation of the dispersion-staining objective are given in detail by McCrone et al [*1*].

Identification

With the dispersion-staining objective positioned at full aperature, synthetic fibers can be differentiated from natural fibers through observations of morphology. Synthetic textile fibers have with few exceptions (for example, recent texturized fibers) a uniform cross-

Received for publication 14 May 1981; revised manuscript received 11 Sept. 1981; accepted for publication 16 Sept. 1981.

[1]Criminalist, Laboratory of Criminalistics, Santa Clara County, San Jose, CA.

TABLE 1—*Identification of synthetic fibers in Cargille high-dispersion liquid ($n_D^{25} = 1.525$) using a polarizing microscope and dispersion staining objective.*

Fiber	Refractive Indices[a]	Becke Line Effects: No Stop		Becke Line Effects: Central Stop		Birefringence	Remarks
Vinyl: Darvan	$n_\parallel$ = 1.465 ± 0.004	$n_\parallel$	out[b]	$n_\parallel$	bright white with pale intermittent yellows, greens, and violets along length[c]	low, −0.008	striated, high contrast
	$n_\perp$ = 1.473 ± 0.007	$n_\perp$	out	$n_\perp$	same as $n_\parallel$		
Acetate	$n_\parallel$ = 1.481 ± 0.006	$n_\parallel$	out	$n_\parallel$	same as for Darvan	low, +0.003	striated
	$n_\perp$ = 1.478 ± 0.006	$n_\perp$	out	$n_\perp$	same as $n_\parallel$		
Triacetate: Arnel	$n_\parallel$ = 1.472 ± 0.004	$n_\parallel$	out	$n_\parallel$	same as for Darvan and acetate	very low, −0.001 to zero	sign changes from negative to zero to positive on long immersion
	$n_\perp$ = 1.472 ± 0.004	$n_\perp$	out	$n_\perp$	same as $n_\parallel$		
Acrylic: Acrilan®	$n_\parallel$ = 1.517 ± 0.010	$n_\parallel$	out	$n_\parallel$	pale blue	low, −0.005	...
	$n_\perp$ = 1.520 ± 0.011	$n_\perp$	out	$n_\perp$	blue		
Orlon	$n_\parallel$ = 1.518 ± 0.006	$n_\parallel$	out	$n_\parallel$	pale blue	low, −0.002	...
	$n_\perp$ = 1.520 ± 0.008	$n_\perp$	out	$n_\perp$	blue		
Vinyl: Vinyon (a vinyl derivative)	$n_\parallel$ = 1.527 ± 0.002	$n_\parallel$	out	$n_\parallel$	blue	low, +0.002	liquid attacks fiber on long immersion
	$n_\perp$ = 1.525 ± 0.002	$n_\perp$	out	$n_\perp$	blue		
Modacrylic: Dynel	$n_\parallel$ = 1.533 ± 0.004	$n_\parallel$	in	$n_\parallel$	orange	low, +0.002	...
	$n_\perp$ = 1.531 ± 0.003	$n_\perp$	in	$n_\perp$	red orange		
Verel	$n_\parallel$ = 1.535 ± 0.003	$n_\parallel$	in	$n_\parallel$	golden yellow	low, −0.004	...
	$n_\perp$ = 1.539 ± 0.003	$n_\perp$	in	$n_\perp$	yellow		
Regenerated protein: Vicara	$n_\parallel$ = 1.538 ± 0.005 (undyed)	$n_\parallel$	in	$n_\parallel$	yellow	low, +0.002	distinguished from modacrylics by uniformity of diameter
	$n_\parallel$ = 1.541 ± 0.009 (dyed)						
	$n_\perp$ = 1.536 ± 0.005 (undyed)	$n_\perp$	in	$n_\perp$	red orange	...	...
	$n_\perp$ = 1.538 ± 0.008 (dyed)						

Glass	$n_{\parallel}$ = 1.549 ± 0.015	$n_{\parallel}$	in	$n_{\parallel}$	white or pale yellow	zero	...
	$n_{\perp}$ = 1.549 ± 0.015	$n_{\perp}$	in	$n_{\perp}$	white or pale yellow	...	...
Rayon: Fortisan	$n_{\parallel}$ = 1.569 ± 0.008 (undyed)	$n_{\parallel}$	in	$n_{\parallel}$	pale yellow	moderate, +0.030	striated
	$n_{\parallel}$ = 1.570 ± 0.020 (dyed)						
	$n_{\perp}$ = 1.520 ± 0.004 (undyed)	$n_{\perp}$	out	$n_{\perp}$	blue	...	...
	$n_{\perp}$ = 1.523 ± 0.023 (dyed)						
Polyamide: nylon	$n_{\parallel}$ = 1.575 ± 0.007 (undyed)	$n_{\parallel}$	in	$n_{\parallel}$	white	high, +0.55	not striated
	$n_{\parallel}$ = 1.579 ± 0.010 (dyed)						
	$n_{\perp}$ = 1.520 ± 0.006 (undyed)	$n_{\perp}$	in	$n_{\perp}$	blue	...	...
	$n_{\perp}$ = 1.525 ± 0.007 (dyed)						
Polyester: Dacron	$n_{\parallel}$ = 1.711 ± 0.011 (undyed)	$n_{\parallel}$	in	$n_{\parallel}$	bright highly refractive white	very high to high, +0.168	...
	$n_{\parallel}$ = 1.714 ± 0.014 (dyed)						
	$n_{\perp}$ = 1.541 ± 0.012 (undyed)	$n_{\perp}$	in	$n_{\perp}$	pale yellow—differs markedly in degree of edge refraction when compared with $n_{\parallel}$	...	...
	$n_{\perp}$ = 1.548 ± 0.013 (dyed)	...	...	...	...	...	...

[a]The refractive indices given are taken from Longhetti and Roche [2].
[b]Becke line movement on focusing up.
[c]Not dispersion-staining colors.

sectional shape and diameter throughout their length. Natural fibers, on the other hand, show a usually systematic variation in cross section along their length: cotton has ribbon-like twists, wood fibers are pitted, bast fibers have nodes, silk has crossover marks, and animal fibers have scales. Furthermore, most natural proteinaceous fibers, such as silk and hairs, have refractive indices greater than 1.525 and exhibit low birefringence.

Table 1 gives the optical properties of several synthetic fibers in the Cargille liquid. Refractive indices in both the longitudinal (parallel to fiber axis) and transverse (perpendicular to fiber axis) directions are listed in order by increasing index in the parallel direction. The refractive index of the liquid (1.525) is approximately central to the average of the principal indices of the fibers included in the study and, as such, represents a reference point from which pertinent fiber indices can be deduced. This deduction is based on the series of colors seen with a dispersion-staining objective using the central stop. The principal colors and the fibers associated with them are given in Table 2.

The synthetic fibers encountered most in forensic science are polyesters such as Dacron®, acrylics such as Orlon®, polyamides such as the nylons, and rayons such as Fortisan®. Dacron has a longitudinal refractive index $n_{\|} \gg 1.525$ and a corresponding absence of dispersion staining, pale yellow transverse dispersion, indicating a slightly higher transverse refractive index $n_{\perp}$, and high birefringence. Orlon is distinguished by pale blue longitudinal and paler blue transverse dispersion, signifying low birefringence and a negative sign of elongation. If the sign of the elongation is in doubt, it can be determined quickly by inserting the Red I retardation plate between crossed polars and slightly opening the substage aperture diaphragm. It is not necessary to remove the central stop. A negative sign confirms Orlon; a positive or indeterminate sign identifies nearly isotropic Vinyon. Nylon exhibits white or very pale yellow central-stop colors in the longitudinal direction and pale blue or blue to blue-magenta in the transverse direction. Rayon is recognized by pale yellow and pale blue longitudinal and transverse dispersion, respectively.

Less commonly encountered fibers include modacrylics such as Dynel® and Verel®, triacetates such as Arnel®, and the acetates. The modacrylics are recognized by pale yellow longitudinal and transverse dispersion colors. Dynel is distinguished from Verel by the sign

TABLE 2—*Dispersion-staining colors for synthetic fibers mounted in Cargille high-dispersion liquid* ($n_D^{25} = 1.525$).

Matching Wavelength, nm	Principal Central Stop Colors	Fibers Indicated by Dispersion	
		Longitudinal	Transverse
$\ll 400$	no dispersion-staining colors in visible; $n \gg 1.525$	Dacron	...
	pale yellow; $n > 1.525$	...	Dacron
420	pale yellow; $n > 1.525$	nylon, rayon	Verel
	gold yellow; $n > 1.525$	Verel, glass	glass
520	orange; $n > 1.525$	Dynel, Vicara	...
560	red orange; $n > 1.525$	...	Dynel, Vicara
625	blue; $n = 1.525$	Vinyon, Orlon, Acrilan	Vinyon, Acrilan, Orlon, nylon, rayon
680	pale blue; $n < 1.525$	...	...
$\gg 680$	no dispersion-staining colors in visible; $n \ll 1.525$	Darvan, acetate, triacetate	Darvan, acetate, triacetate

of elongation: positive for Dynel and negative for Verel. Acetates and triacetates are characterized by very low refractive indices and either small or nonexistent birefringence. The two are distinguished from each other by the sign of elongation: positive for acetates and negative or zero for triacetates.

A condensed scheme designed to lessen the complications introduced by inclusion of all possible synthetic fibers is given in Fig. 1. Omitted are the less common and nontextile fibers: Vinyon, Darvan®, Vicara, polyethylene, saran, and polystyrene. Vinyon, Darvan, and Vicara were considered in Table 1. Saran, polyethylene, and polystyrene are not present except under the most unusual circumstances, and their presence is indicated by exceptionally wide diameters, that is, well in excess of 200 μm. Their optical properties, as determined by a polarizing microscope, have been given by Longhetti and Roche [*2*].

Discussion

The problems associated with the scheme are minimal. Moderate dyeing does not seriously affect the central stop colors. If the fiber is deeply dyed, its color should be viewed with the objective at full aperture and an assessment made of possible dye absorption effects on the central stop colors.

Heavy concentrations of delustrant particles reduce the vividness of the central stop colors but do not eliminate them. Wide variations in ambient temperature can have an effect inasmuch as the refractive index of the liquid varies linearly with temperature. For Cargille liquid, the temperature coefficient of the refractive index is 0.00047. All color effects given in the tables and figure were based on observations made at room temperatures of 18 to 20°C; thus, the actual refractive index for the liquid used, for 25°C and sodium light (n_D^{25}) = 1.525, was 1.5274 to 1.5283. Considering the refractive indices of the fibers studied (1.47 to 1.73), this variation in index of the liquid should have had a negligible effect on the colors observed.

Comparison of values of $n_\parallel$ and $n_\perp$ for synthetic fibers presented in the literature [*2*] reveals that fiber types show differences in refractive index according to manufacturer.[2] The differences are rarely substantial and no misidentifications should result, provided that the microscopist is cognizant of the possible range of differences. Indeed, these differences can provide individualizing information when the problem of determining possible common source is at hand. Furthermore, because of the high color resolution of the central-stop method, the potential exists for distinguishing identical fibers that have undergone different wear and laundering.

The efficacy of the proposed scheme will become more evident as the microscopist gains orientation through experience with the technique. This orientation is assisted by having a set of known synthetic fibers mounted in liquid available for ready and constant reference. The standards should include dyed as well as undyed and both bright and delustered fibers. Reasonably permanent mounts can be obtained by edging the coverslips (18 by 18 mm) with molten wax applied with the end of a microscope slide. Paraplast, a medium used for mounting tissues for sectioning, has been found to be satisfactory. Prolonged immersion of the fibers in Cargille liquids usually has no discernible effect on their optical properties. Exceptions are some samples of Arnel®, which change from negative to isotropic and finally to positive after several hours, and Vinyon, which dissolves very slowly. Eventually, experience together with thoughtful self-critiqueing will enable near-instantaneous identifications in most instances without the need for reference to identification tables.

[2]H. J. Funk, "A Simple Method for Classifying Man-Made Fibers," unpublished data, Centre of Forensic Sciences, Toronto, Ontario, Canada.

Mount fibers in Cargille high dispersion liquid $nD^{25} = 1.525$.
Make microscopic observations of edge colors using polarized light and central stop of a dispersion-staining objective.
For sign, use full objective aperture and Red I compensator between crossed polars.

$n\parallel$ white with rainbow edge effects		$n\parallel$ pale blue-blue	$n\parallel$ gold-orange		$n\parallel$ white-yellow white	$n\parallel$ yellow	$n\parallel$ white	$n\parallel$ white, highly refractive edges
$n\perp$ same as $n\parallel$		$n\perp$ blue	$n\perp$ yellow-red orange		$n\perp$ same as $n\parallel$	$n\perp$ blue	$n\perp$ blue	$n\perp$ pale yellow
Acetates Triacetates			Modacrylics		Isotropic			
sign (+)	sign (−)*		sign (+)	sign (−)				
Acetates	Triacetates (Arnel)	Acrylics (Orlon)	Dynel	Verel	Glass	Rayon	Polyamides (Nylon)	Polyesters (Dacron)

* also isotropic

FIG. 1—*Scheme for rapid identification of synthetic fibers.*

Conclusions

The use of fibers as evidence has long been recognized; however, it is likely that the full potential offered by this type of evidence has not been realized. There are several reasons for this. Foremost among these is the normally occult nature of fiber evidence, except in those unusual instances where the number, location, and color brightness of the fibers are such that they cannot be overlooked except by the most determinedly inattentive worker. Unfavorable circumstances are common, especially in those cases involving crimes against persons where the problem is proving contact by transfer of fibers. Such circumstances include finding fibers few in number, low in color brightness, and intermixed with many and various other fibers. The problems can be of such staggering magnitude that the forensic scientist can be forgiven if he or she looks to other approaches for developing proof. The scheme of identification described above is intended to lessen the inherent problems associated with fiber evidence.

Acknowledgments

The author gratefully acknowledges the close attention to detail given by Walter C. McCrone in reviewing the manuscript.

References

[*1*] McCrone, W. C., McCrone, L. B., and Delly, J. G., *Polarized Light Microscopy*, 8th ed., Ann Arbor Science Publishers Inc., Ann Arbor, MI, 1978.

[*2*] Longhetti, A. and Roche, G. W., "Microscopic Identification of Man-Made Fibers from the Criminalistics Point of View," *Journal of Forensic Sciences*, Vol. 3, No. 3, July 1958, pp. 303–329.

Address requests for reprints or additional information to
Wilkaan Fong
Laboratory of Criminalistics
Santa Clara County
1557 Berger Drive, Suite B-2
San Jose, CA 95112