TECHNICAL NOTE

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A Flowchart System for the Identification of Common Synthetic Fibers by Polarized Light Microscopy

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ABSTRACT: A flowchart system for identifying common types of synthetic fibers is described. Based on polarized light microscopy, the system allows the rapid identification of the nine generic classes of synthetic fibers most often encountered in casework.

KEYWORDS: forensic science, criminalistics, fibers, fiber identification, polarized light microscopy

The identification of the generic class of an unknown synthetic fiber is one of the first and most important skills acquired when training in fiber examination. The optical properties of synthetic fibers have been well documented (1,2) and allow the most frequently encountered types to be readily distinguished. This paper will describe a flowchart system for identifying common synthetic fibers which has been useful for training in our laboratory. The system, based on polarized light microscopy (PLM), uses simple Becke line techniques and observation of retardation colors (3). No precise determinations of birefringence or refractive indices are necessary. The system is easily used by anyone with a basic knowledge of PLM and rapidly allows a trainee to become familiar with the distinguishing optical properties of synthetic fibers.

The Flowchart System

The flowchart system, illustrated in Fig. 1, divides the common synthetic fibers into four basic classes. A fiber is mounted in 1.530 high dispersion refractive index oil (Available from R. P. Cargille Laboratories, Cedar Grove, N.J.) and its retardation colors are observed between crossed polars. The observed retardation colors are compared to the Michel-Levy chart to determine into which order they fall, and based on this the fiber is assigned to one of the four groups. Use of a full wave plate at this point may provide additional help in orienting oneself on the chart. Since only a very general estimate of retardation colors is necessary, the determination can usually be made without difficulty even on deeply colored fibers. Further identification within each group is based primarily on determination of the sign of elongation and the refractive indices (relative to the mountant) for light polarized parallel to and perpendicular to the length of the fiber ($n_{\parallel}$ and $n_{\perp}$). Guidelines for further identification are described below.

Group 1—Isotropic

Glass fibers can usually be identified by their isotropic nature, although in some cases they will show a slight, non-uniform birefringence due to strain. In such cases, morphological features can be used to identify the fibers as glass. Microscopical examination may also help to indicate a possible source of glass fibers. Fibers from glass fabric will be featureless rods, uniform in diameter, usually with no adhering material. Automotive fiberglass will also be in this form, but will usually have a birefringent binder adhering to the fibers. Insulating fiberglass will show a wider range of lengths and diameters and, depending upon the manufacturing process, may also contain spheres and teardrop shaped slugs. Most, though not all, insulating fiberglass will be coated with a colored resin which adheres to individual fibers in small blobs or droplets.

Group 2—Low 1st Order

The fibers in this group (acetate, triacetate, acrylic and modacrylic) will all show first order gray or white retardation colors and have birefringences <0.010. Some triacetates will show birefringences so close to zero that they appear nearly isotropic. In such cases, an increased level of illumination and careful observation with a full wave plate in place will usually reveal their birefringent nature. A triacetate fiber which shows no birefringence may still be identified by morphology. The fibers in group 2 are further subdivided by their sign of elongation, determined by inserting a full wave plate with its slow (z) direction parallel to the length of the fiber. Fibers with a positive sign of elongation will show a blue color, while those with a negative sign will appear orange. Acetates, most triacetates and Dynel[2] modacrylic will show a positive sign of elongation, while acrylics and other modacrylics (for example, Verel,[3] Elura,[4] SEF[4]) will show a negative sign of elongation. Triacetates will occasionally show a negative sign of elongation, but their multilobal cross-section, along with their low birefringence, will allow them to be properly classified. Acrylics

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[2]Union Carbide Corp.
[3]Tennessee Eastman Co.
[4]Monsanto Textiles Co.

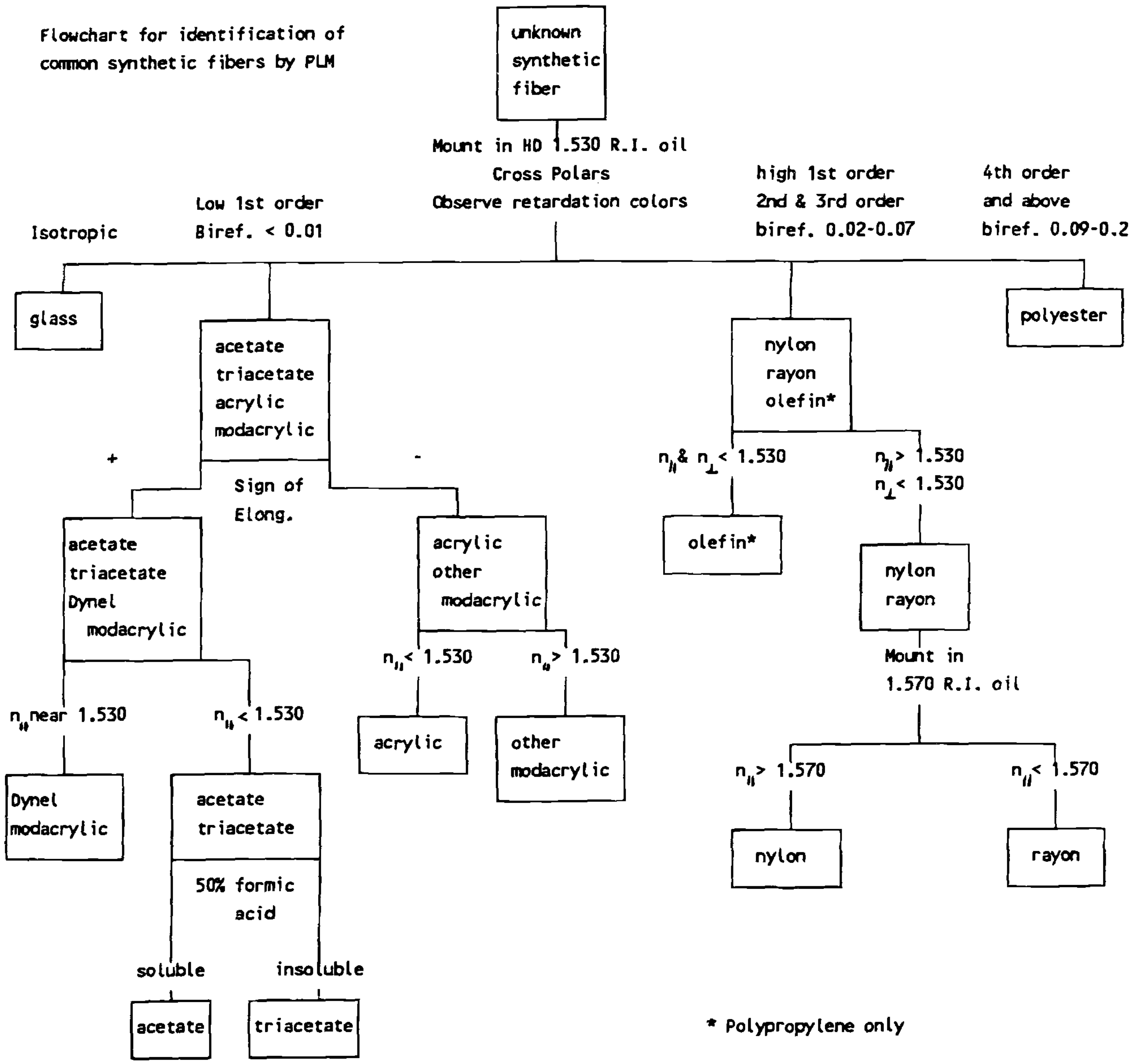

FIG. 1—*Flowchart system.*

are readily distinguished from modacrylics by noting whether $n_{\parallel}$ is higher or lower than 1.530 (by observation of Becke line movement when focus is raised). Acetates and triacetates may be distinguished from Dynel modacrylic by their higher contrast in 1.530 refractive index oil and by their characteristic multilobal cross-sections. Acetates and triacetates may be difficult to distinguish microscopically, but several solvents (including 50% formic acid) will readily differentiate them, as will a melting point determination (4).

Group 3—High 1st Order, 2nd and 3rd Order

The fibers in this group (olefin, nylon and rayon) will all show moderate retardation colors and birefringences between 0.020 and 0.070. In some instances, thicker nylon fibers may show retardation colors into the 4th and 5th orders, comparable with those of smaller diameter polyester fibers. A little experience in gaging retardation colors relative to diameter and in observing the degree of contrast change when switching between the $n_{\parallel}$ and $n_{\perp}$ orientations of the fiber will usually eliminate confusion in such cases. Alternatively, a questionable fiber can be mounted in 1.600 refractive index oil, in which polyester will show a higher $n_{\parallel}$ and nylon will show a lower $n_{\parallel}$. Olefin fibers are distinguished from nylon and rayon by the fact that both $n_{\parallel}$ and $n_{\perp}$ are <1.530 for olefins, while $n_{\parallel}$ is >1.530 for the other two. Note that only polypropylene is included in the olefin classification for purposes of this scheme, as polyethylene fibers are rarely encountered in casework. In some cases, nylon and rayon may be distinguished without an additional mount by observation of characteristic nylon cross-sections (trilobal or square perforated). If the unknown fiber shows a round or near round cross-section however, no such differentiation is possible and an additional mount in 1.570 refractive index oil should be used. Nylon will show $n_{\parallel} > 1.570$ and rayon will show $n_{\parallel} < 1.570$.

Group 4—4th Order and Higher

Among the commonly encountered synthetic fibers, only polyester falls into this group. Polyester will show birefringence in the range of 0.090 to 0.200 as well as a large difference in contrast between the $n_{\parallel}$ and $n_{\perp}$ orientations of the fiber. The polyethylene terephthalate (PET) and polycyclohexylene-dimethylene terephthalate (PCDT) varieties of polyester can be easily distinguished, as PCDT fibers will have a birefringence close to 0.100 and $n_{\parallel} < 1.660$, while PET fibers will have a birefringence above 0.140 and $n_{\parallel} > 1.660$. Polyester fibers with large diameters may show such high retardations that they appear white. This high order white can be easily distinguished from the low order white of acrylics and acetates by inserting a full wave plate. Polyesters will remain white, while acrylics and acetates will appear blue or orange.

Less Common Synthetic Fibers

While virtually all of the synthetic fibers seen in routine casework are encompassed by this identification scheme, other types may occasionally be encountered and the fiber examiner should be familiar with their distinctive characteristics (1,2,5,6):

Aramid—Extremely high birefringence with both $n_{\parallel}$ and $n_{\perp} > 1.600$

Fluorofiber—Extremely low refractive indices; the only fiber with $n_{\parallel}$ and $n_{\perp} < 1.460$.

Hydrofil® Nylon[5]—Moderate birefringence, with slighly different refractive indices than other nylons ($n_{\parallel} \approx 1.567$, $n_{\perp} \approx 1.523$).

Novoloid—Very low birefringence, with $n_{\parallel}$ and $n_{\perp}$ both ≈ 1.650

Polybenzimidazole (PBI)—Moderate birefringence, with both $n_{\parallel}$ and $n_{\perp} > 1.700$.

Polyethylene—Optical properties similar to nylon ($n_{\parallel} \approx 1.570$, $n_{\perp} \approx 1.520$) but with extremely low density (<1.0) and melting point (approx. 130°C). Often seen in tape form when encountered.

Saran—Negative sign of elongation, but with $n_{\parallel}$ and $n_{\perp}$ between 1.600 and 1.620.

[5]Allied Signal, Inc.

Spandex—Very high elasticity, much higher than any other fiber.

Conclusion

A flowchart system has been described that rapidly allows a beginning fiber examiner to distinguish and identify common synthetic fibers. While this system will apply to the vast majority of fibers encountered in casework, an examiner must always be aware of less common or newly developed fibers that may fall outside the system's scope and which may require additional tests in order to be identified.

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