TECHNICAL NOTE

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A Guide to the Rapid Screening, Identification, and Comparison of Synthetic Fibers in Dust Samples

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ABSTRACT: A microscopical scheme for the examination, identification, and comparison of the synthetic fibers present in dust is proposed. The method involves mounting a sample of dust in a medium with a refractive index of 1.525 at 25°C, and collecting morphological and optical data about the synthetic fibers present in the dust specimen. The data are then used to identify each fiber's generic class and to compare fiber samples. This scheme was designed for examiners with little experience in synthetic fiber examination.

KEYWORDS: forensic science, synthetic fibers, dust, microscopy

The occurrence and role of textile fibers in forensic science investigations has been well documented [*1–12*]. Although the value of fiber evidence is well known, many forensic science investigators continue to disregard fiber evidence entirely, or treat it as a secondary form of physical evidence. Perhaps the reason for this fact is that, in the past, very few practical identification schemes, which address the problems of everyday forensic science casework, have been published [*13,14*].

Today, with the enormous production and manufacturing of synthetic fibers for all types of textile materials, our environments are literally inundated with trace fibers. In urban centers, especially, dust samples composed of small fragments of synthetic fibers rolled together into balls are ubiquitous (a form of urban soil). Like soil, which forms from the erosion and degradation of the rocks, minerals, and organic matter in the environment, dust is formed from the wearing down of textiles (rugs, mats, draperies, clothing, and so forth), as well as the hair from animals and people and other materials in the environment. As soil often represents the geological area in which it is formed, dust is often representative of the location in which it forms (an apartment, a home, an office, a store, a factory, and so forth), and can thus be used to characterize a location, or associate those who live, work, or otherwise frequent the location.

Forensic dust studies often involve hundreds of fibers. Therefore, any proposed scheme of identification and comparison of synthetic fibers in dust specimens must enable the micro-

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analyst to screen, identify accurately, and compare a large variety of fiber types as rapidly as possible, with a minimum amount of sample manipulation. The method proposed here meets all these requirements and has been successfully used by the author in his casework for many years. This method was developed from two primary sources: the author's research and the methods and rationale taught at the F.B.I. hair and fiber course.

Methods and Materials

Sample Preparation

The dust specimen is mounted on a microscope slide in permount (refractive index [RI] 1.525 when dry), a Cargille liquid, or a mixture of Cargille liquids with a RI of 1.525 at 25°C. The specimen is then covered with a No. 1½ cover glass. Before mounting, the specimen may be teased with two needles to loosen the fibers and debris composing the dust. The preparation is then observed under a polarized light microscope (PLM).

Examination of Unknown Man-Made Fiber in Dust

The microanalyst upon examining a preparation of dust will observe a variety of synthetic fibers as well as hairs, vegetable fibers, and other debris. At this point, the examiner must, with his or her eyes, single out the fiber in question and make the following observations. Information concerning the fiber's morphology is collected first. Next, the relative refractive indices (RRI) of the fiber's $N\parallel$ and $N\perp$ directions as they compare to the mounting medium's RI (1.525) are obtained by the Becke line method using plane polarized light. In the Becke line method, the fiber's elongated axis is made parallel to the vibrational (preferred) direction of the polarizer. The movement of the Becke line is noted when the microscope's focus is raised (the Becke line moves towards the medium of higher RI under these conditions). The fiber's elongated axis is then made perpendicular to the preferred direction of the polarizer and the movement of the Becke line is noted in this orientation (see Fig. 1 for orientation of the fiber and Fig. 2 for Becke line movement). The fiber is then observed between crossed polars. If the fiber is anisotropic, the amount of retardation the fiber exhibits is estimated using an interference chart and the appropriate compensator(s). The fi-

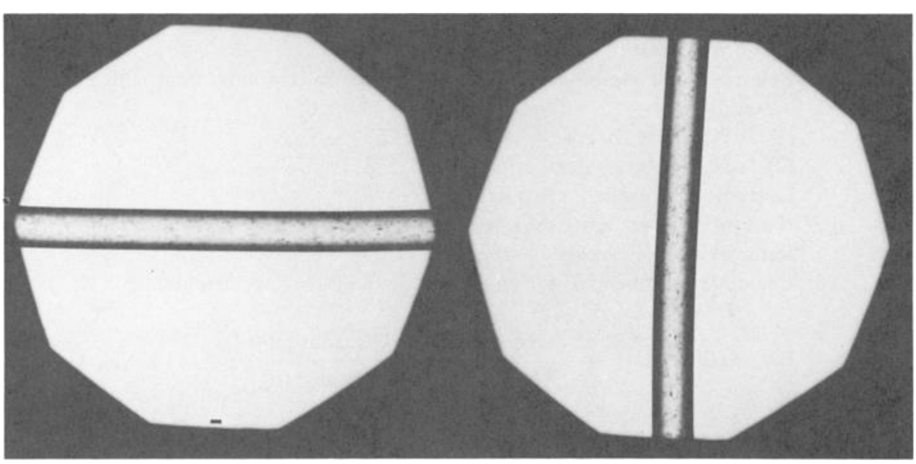

FIG. 1—*The fiber specimen is oriented in the* $N\parallel$ (left) *and* $N\perp$ (right) *directions with respect to the east-west orientation of the polarizer. The bar in the photomicrograph is equal to 10 μm.*

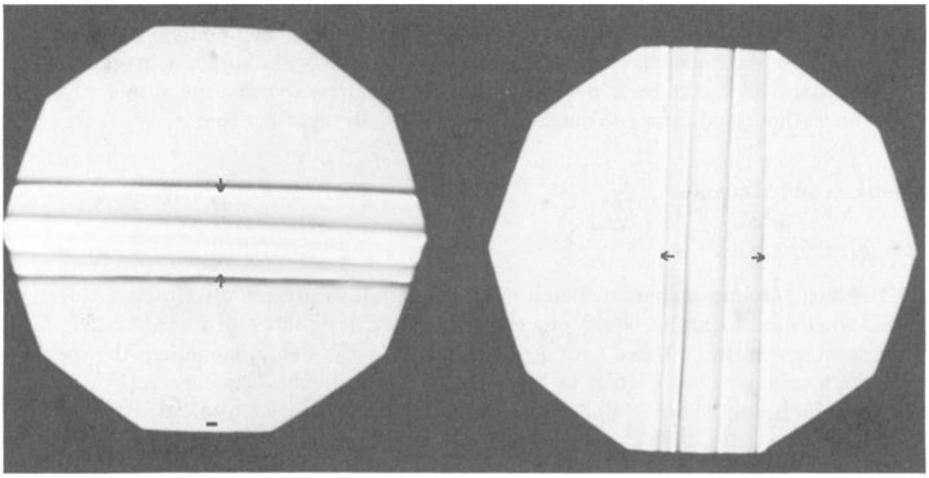

FIG. 2—*The Becke line* (white halo) *moves towards the medium of higher refractive index when the focus is raised. On the left, the Becke line moves towards the fiber. On the right, the Becke line moves towards the mounting medium. The bar in the photomicrograph is equal to 10 μm.*

ber's sign of elongation (SE) is determined at this stage of the examination. The fiber's estimated birefringence (EB) is computed using the collected data. Other comparative information about the fiber's appearance: dulling agent (Fig. 3); treatment: twisted, crimped (Fig. 4); and optical properties: degree of relief (Fig. 5); and so forth is collected. All the data are recorded in the examiner's notes or on a fiber data sheet. A sample data sheet is shown in Appendix A. The following is a list of the data necessary for the identification of an unknown man-made fiber:

1. Fiber's morphology:
   (a) longitudinal appearance, smooth, striated;
   (b) cross-sectional shape; and
   (c) diameter or lobe thickness in micrometres (μm).
2. Fiber's optical data:
   (a) Relative refractive index (RRI): (observe Becke line movement with plane polarized light).
      (1) Is N∥ above, below, or equal to 1.525?
      (2) Is N⊥ above, below, or equal to 1.525?
   (b) Isotropic or anisotropic? (polars crossed)
   (c) If anisotropic, estimate the fiber's retardation, use fixed or variable compensators. Refer to an interference chart.
   (d) Calculate the fiber's birefringence using the following formula:

$$\frac{\text{Birefringence (Bi)}}{\text{Bi} = (N\| - N\perp)} = \frac{\text{Retardation } (r)}{\text{Thickness } (t)}$$

(Plot t and r on an interference chart and estimate its birefringence or calculate it from the data using the cited formular.)

   (e) Sign of elongation positive or negative.

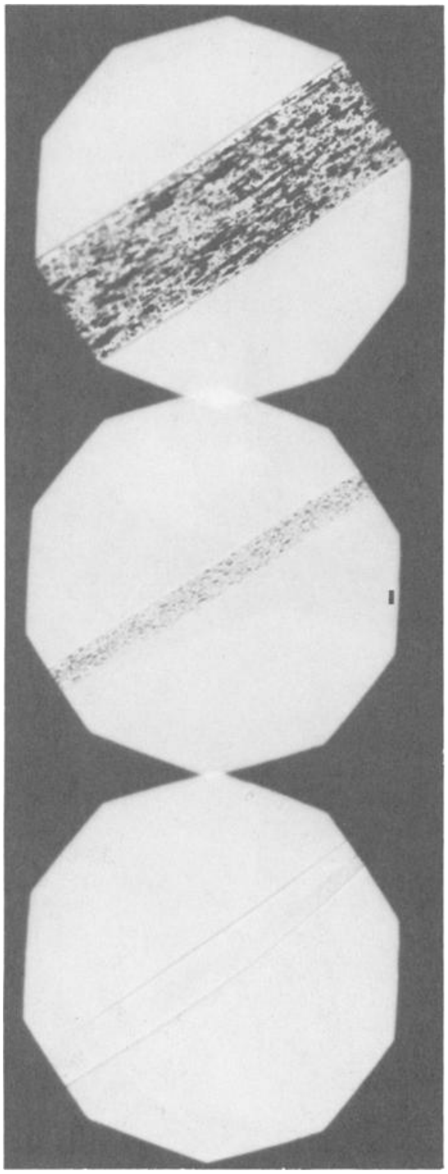

FIG. 3—The appearance of fibers with and without dulling agent (TiO_2). From left to right: Bright (no dulling agent), semi-dull, and dull. The bar in the photomicrograph is equal to 11 μm.

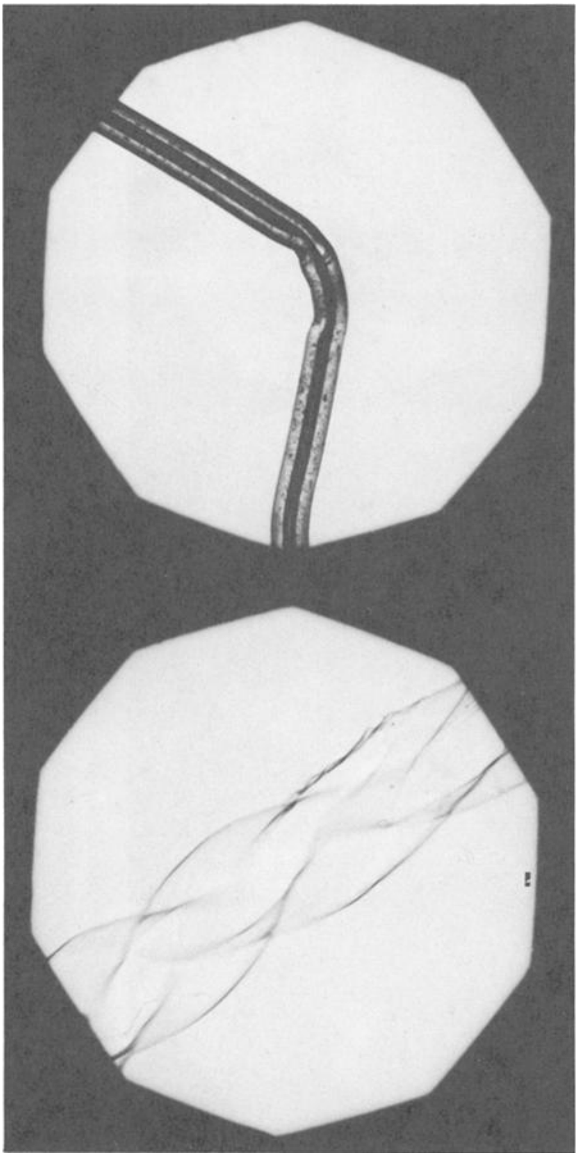

FIG. 4—*Two forms of fiber treatment. The fiber on the left has been twisted. The fiber on the right has been crimped. The bar in the photomicrograph is equal to 10.5 μm.*

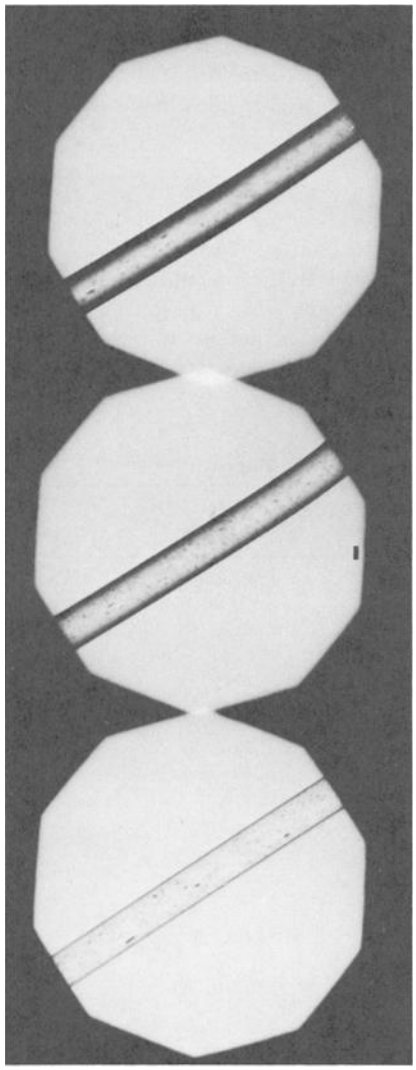

FIG. 5—The various degrees of relief are exhibited from left to right: low, medium, and high relief. The bar in the photomicrograph is equal to 11 μm.

3. Additional comparative information:
   (a) Color, dyed or undyed.
   (b) Dulling agent (TiO_2) present?
   (c) Is the fiber crimped, twisted, other?
   (d) Note the degree of relief.
   (e) Is fiber pleochroic?

To determine the generic classification of an unknown fiber, the collected data in Appendix A is compared against the information in Table 1 and Fig. 6. Each type of fiber in the dust specimen is identified in the same manner. If a comparison of the dust is desired, the questioned and known specimens can be compared side by side on a comparison microscope composed of two polarized light microscopes which have been optically bridged together.

Discussion

To date, this scheme of identification and comparison of the synthetic fibers present in dust has had few problems associated with it. When using this method it is important to keep in mind that it was designed for the identification of the generic classes of synthetic, fibers most often encountered in dust. Therefore, the rarely seen classes of synthetic fibers were not included in this study. Despite this, the method has proven to be valuable in everyday casework situations. It allows for the rapid and accurate identification of single synthetic fibers

TABLE 1—*The generic classes of synthetic fibers commonly occurring in dust sample.*[a]

Generic	RRI N‖/N⊥	EB (Range)	SE	Usual Cross Sections
Acetate	both < 1.525	0.002-0.005	(+)	serrated
Triacetate	both < 1.525	almost 0.0 (slight)	(+)/(−)	serrated
Acrylic	both < 1.525 N⊥ close to 1.525	0.001-0.006	(−)	round, ovoid, dogbone, bean, mushroom
Modacrylic	both > or < 1.525	0.001-0.004	(+)/(−)	dogbone, irr. multilobed, ribbon
Aramid	both > 1.525	0.22-0.40	(+)	round, bean, peanut
Polyamide (Nylon 6, 6.6,)	N‖ > 1.525 N⊥ close to 1.525 N⊥ > or < 1.525	0.049-0.060	(+)	round, trilobal, tetralobal,
(Qiana®)	N‖ > 1.525 N⊥ < 1.525	0.036	(+)	trilobal
Glass	isotropic (range 1.520-50)	...	...	round, off round
Olefin (Propylene)	N‖ > 1.525 N⊥ < 1.525	0.028-0.032	(+)	round, trilobal,
Polyester	both > 1.525	0.112-0.180	(+)	round, ovoid donut, trilobal polygonal, swollen ribbon
Rayon (Viscose and modified)	N‖ > 1.525 N⊥ < 1.525	0.020-0.039	(+)	serrated/multilobal bean, round
Chlorofiber (Vinyon)	both = >1.525 (or close)	almost 0.0-0.005	(+)	round, dogbone
Vinal	N‖ > 1.525 N⊥ < 1.525	0.030	(+)	dogbone

[a]RRI = relative refractive indices, EB = estimated birefringence (N‖ − N⊥), and SE = sign of elongation.

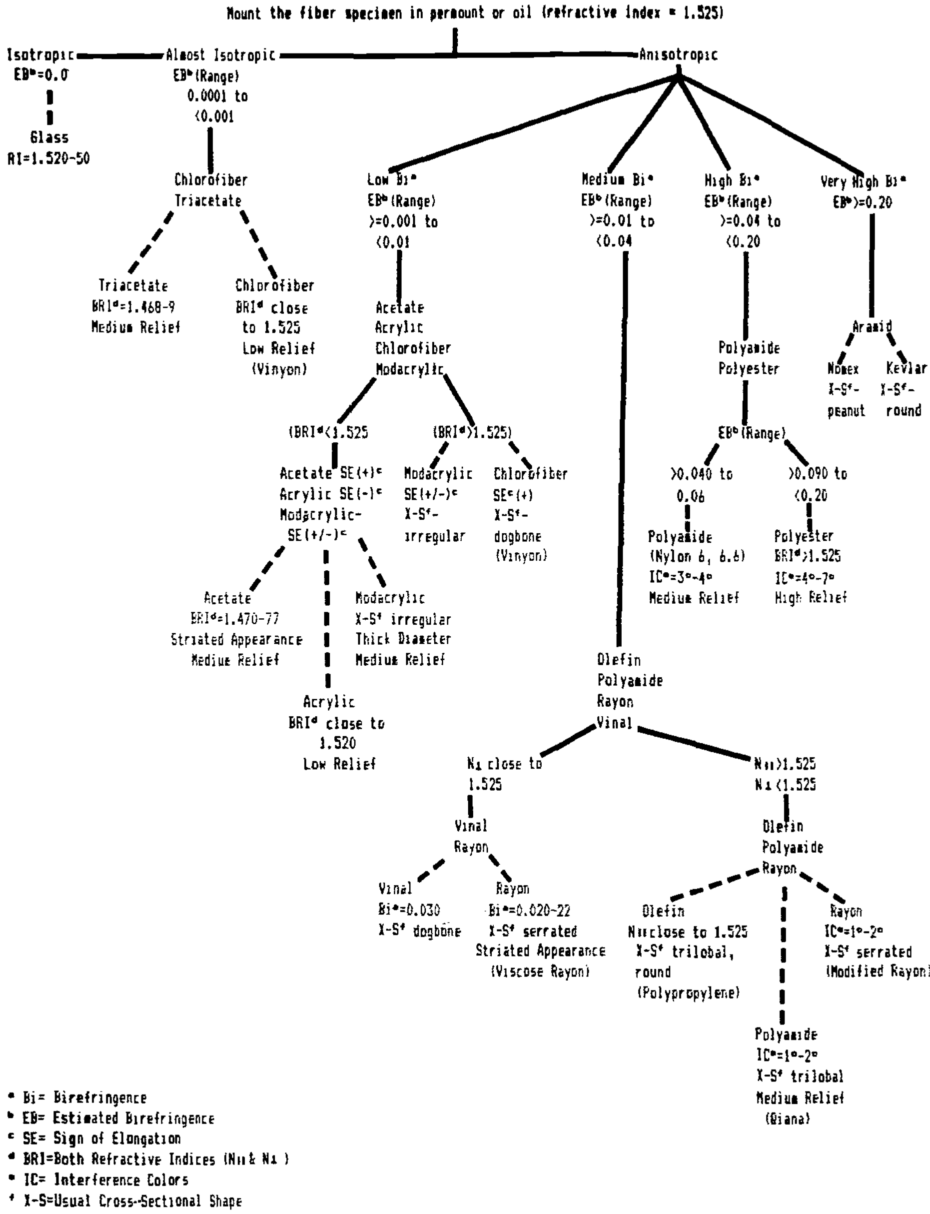

FIG. 6—*A flow chart used for the generic classification of man-made fibers commonly occurring in dust.*

in dust samples with a minimum amount of effort and sample manipulation. The method also allows for the side-by-side comparison of fibers in dust with no additional sample preparation.

The problems associated with dyed fibers have been minimal. Only in the case of opaque fibers has the method met with some difficulty. In the case of heavily dyed or opaque fibers the aperture stop of the condenser is closed down to its smallest opening. This allows for the optimum image of the Becke line to be achieved.

The data in Table 1 and Fig. 6 enable even an inexperienced examiner to identify correctly the generic classification of questioned fibers. The method is nondestructive. Consequently, the fibers are available for other forms of analyses if necessary and reexamination by other experts, if requested. Although the method was developed for the study of synthetic fibers occurring in dust, it can be and has been successfully utilized in other types of forensic fiber investigations.

Finally, the method is suited to most forensic science laboratories. It is fast, easy to learn . . . requiring little previous experience on the part of the examiner in the identification of synthetic fibers, and most forensic science laboratories already possess the necessary equipment, a polarized light microscope.

Conclusion

The significance of fiber evidence has long been known. Fibers have been used to associate people, places, and things involved in criminal investigations as well as reconstruct the events of the case. In spite of this, many forensic science investigators continue to use fiber evidence only as a last resort. This classification scheme was developed to help make the identification and comparison of synthetic fibers occurring in dust (an often difficult task) easier. In turn, it is hoped that this method will encourage forensic science investigators to use dust and all other forms of fiber evidence more frequently in their casework as a source of investigative information and proof.

APPENDIX A

A data sheet with all the information necessary for the classification of synthetic fibers. Circle and/or write in the appropriate data.

Fiber Morphology

Longitudinal: smooth striated irregular other __________
Cross-sectional shape: __________
Diameter or lobe(s) thickness in μm: __________

Optical Data

Relative refractive indices—relative to medium (1.525)
N parallel (N‖) above below equal
N perpendicular (N⊥) above below equal
Crossed polars: isotropic anisotropic
Estimated retardation in nanometers (nm): __________
(Interference colors)
Estimated birefringence: __________
Sign of elongation: positive negative

Other Comparative Information

Color: __________ dyed undyed
Dulling agent (TiO_2): bright semi-dull dull
Treatment: crimped twisted other __________
Degree of relief: low medium high
Pleochroic: yes no
Other information: ____________________

(Refer to Table 1 and Fig. 6 to determine the fiber's generic class. The information for Table 1 was obtained in part from the author's research, and in part from several references [*15-21*].[2]

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