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Fiber Evidence: Laboratory Methods and Observations from Casework

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ABSTRACT: Simple, step-by-step methods are described for developing fibers as evidence. The methods involve recovery of adherent fibers from the surfaces of textile articles with a readily fashioned adhesive rolling device, systematic search of the recovered fibers, segregation, characterization, and comparison. Also described are methods for photomicrographic recording. The methods were developed from experience to meet the practical needs of a forensic science laboratory worker. Observations drawn from case experience are given and case illustrations are described.

KEYWORDS: criminalistics, fibers, microscopy

In 1953, Kirk [*1*] described laboratory methods for examining textile fiber evidence. The methods involved vacuum sweepings of clothing articles, categorization and segregation of fibers recovered from sweepings, and microscopic comparisons. During the 30 years since the publication of Kirk's book, no comprehensive article on this subject has appeared in the forensic science literature. This is troubling in consideration of the length of time which has elapsed and the difficulties encountered in the execution of Kirk's methods.

In recent years, the author's attention has been drawn to the problems inherent in processing a complex criminal case in which fibers are involved. This attention has resulted in the development of an improved comprehensive method for fiber examination, involving rapid recovery of adherent fibers from fibrous articles using an adhesive rolling tool, segregation without the necessity of sorting dishes, rapid identification including today's more prevalent synthetic fibers, systematized comparisons of many fibers from several sources, and rapid photomicrographic recording of results.

Experience has shown that the methods developed have substantial advantages over previous methods. The purpose of this article is to give the details of the methods and offer some observations drawn from case work in which the methods were used.

Experimental Procedures

Recovery

The article, which can be clothing, carpeting, bedding, fabric-covered furniture, and others, is examined under good lighting for readily evident fibers. Either holding the article

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at various angles or varying the angle of incidence of the light source can be useful. If fibers are seen they are readily lifted with the adhesive surface of a 150-mm (6-in.) length of transparent tape. After lifting, the tape is pressed lightly onto a clean plastic polyethylene film surface. A plastic bag can be used. Identification of the source of the fibers can be placed on the film surface with a felt-tipped permanent marking pen.

If adherent fibers are not readily seen, or, if seen, are scattered, an adhesive roller is used. Such a roller, ready for use, is illustrated in Fig. 1. It is prepared from a paint roller with a deep acrylic fiber nap over which a tight fitting polyethylene bag has been drawn. The roller is of the variety commonly used for water-based paints. With the bag in place, a strip of 20-mm (¾-in.) wide double-coated adhesive tape is tightly spiralled onto the plastic-covered roller from end to end. The paint roller illustrated is approximately 50 mm (2 in.) in diameter and 75 mm (3 in.) in length. The plastic bag is 75 mm (3 in.) in width and 200 mm (8 in.) in length.

Rollings of the article are continued until the adhesiveness of the tape is lost. The degree of loss can be felt with experience. Normally, one roller preparation is sufficient for an article such as a shirt or a pair of trousers. Larger surfaces may require several adhesive sleeve preparations.

When rolling is completed the plastic bag is pulled from the roller and the surface of the bag which is free of adhesive tape is labeled as to the source. If examinations are not to be performed immediately the rolling can be stored in a larger bag.

Search

The adhesive sleeve is pressed flat on the surface of a clean 200- by 250-mm (8- by 10-in.) polyethylene bag. A microscope slide is readied for receiving fibers from the adhesive surface. This is done by spreading three to four drops of Cargille high dispersion (H.D.) refractive index liquid $n_D^{25} = 1.525$ onto its surface where n = refracture index, 25 = 25°C, and D = Sodium D live in the visible spectrum. A pair of jeweler's forceps, with its tips wetted with the same liquid, is used to strip the fibers of interest from the adhesive. The prior wetting of the forceps tips softens the adhesive under the fiber, thus permitting rapid removal. Also, it guards against loss of fibers during their transfer to the prewetted slide. Once transfer has been effected the fibers cannot be lost.

Searching for fibers of evidentiary interest is performed with a stereoscopic microscope at approximately ×10 magnification. Fibers transferred to the adhesive that can be attributed to the fabric of the article source are readily recognized through their color and frequency.

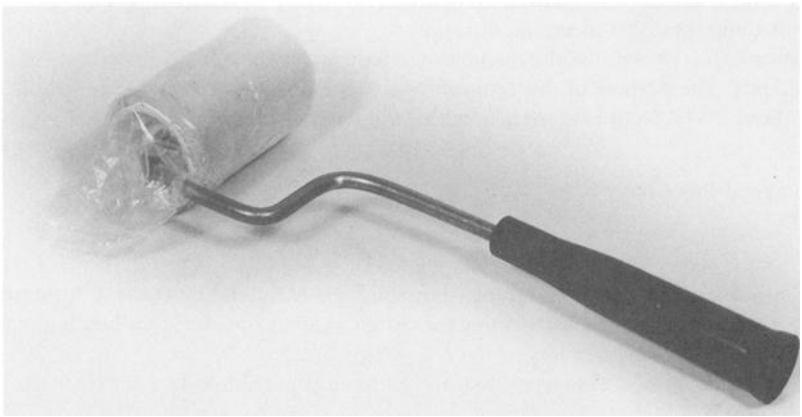

FIG. 1—*Adhesive rolling device for recovering adherent fibers.*

Such background fibers are excluded from consideration during the search. After each transfer has been completed, the forceps tips should be inspected through the stereoscopic microscope to ensure that the transfer has actually been effected.

Transfer of fibers from a single-coated adhesive strip that has been fixed to plastic polyethylene film is achieved in the same manner, except that the cellophane over the fibers is cut and laid back to expose the fibers attached to the adhesive. Cutting can be performed with a Bard Parker scalpel blade; either Style 11 or Style 15 is suitable.

The search of the adhesive rollings should proceed systematically. A practical approach is to search from end to end and from top to bottom while maintaining orientation. Such orientation is conveniently performed through sequential overlapping of microscope fields. A field of view at ×9 magnification through a Greenough type stereoscopic microscope extends across an approximate 16-mm (⅝-in.) diameter on the search surface. At this magnification, systematic scan searching and recovery of fibers from a normal rolling requires approximately 15 to 30 min.

Segregation

After transfers have been completed, the fibers, now on a microscope slide under a refractive index liquid, are segregated to localized areas on the slide. The segregations are performed under a stereoscopic microscope at approximately ×10 magnification and are based upon differences in physical properties: color, shade of color, width, uniformity along length, and presence or absence of regular angular characteristics along the length. When a variety of colors are represented, the segregation locations on the slide should be systematized, for example: from left to right—blue, green, yellow, orange, red; from top to bottom, dark to light.

A needle probe in conjunction with a jeweler's forceps is used to perform the segregations. A normal slide should include no more than eight to ten segregations, with each segregation including one to several fibers. If more are required, additional slides should be used.

A 22- by 50-mm, No. 1½, cover slip is placed over the preparation. Excess liquid may be soaked up from along the cover slip edges by using a small twisted piece of absorbent tissue. The cover slip is immobilized by applying molten sealant to its edges with the end of a microscope slide. The application is done with the slide carrying the sealant held at a very low angle and in such a manner as to produce a continuum overlap from cover slip to slide. An excess of sealant is to be avoided.

The edge sealant consists of melted Parowax®, Permount®, and Dow Corning Silicone Oil 710, combined at a proportion of 6:12:1 by volume, respectively. The mixture is heated with stirring on a small hot plate at a temperature of 110°C until the solvent in the Permount has been removed. Heating should take place in a vented hood to avoid the somewhat disagreeable odor, especially if the mixture is to be kept molten over an extended time period.

With the cover slip fixed in place, the slide is examined under the stereoscopic microscope and fibers are selected for further study. The selections are line-marked directly on the cover slip with a felt-tipped permanent marker. The line marking is placed to cross over the fiber or fibers selected and its free end is assigned a number. Appropriate labeling of the slide as to the source of the fibers and the assignment of a slide number complete the segregation phase. A slide, readied for further study in the manner described, is shown in Fig. 2.

A slide mount bearing a representative sampling of reference fibers—plucked from the article under examination—is prepared in the same manner.

Identification and Characterization

A polarizing microscope equipped with a ×10 dispersion staining objective is used to identify and characterize the mounted fibers. Either a ×7 or a ×10 ocular can be used. The desired fiber or fiber group is located by using the numbered line marking on the cover slip.

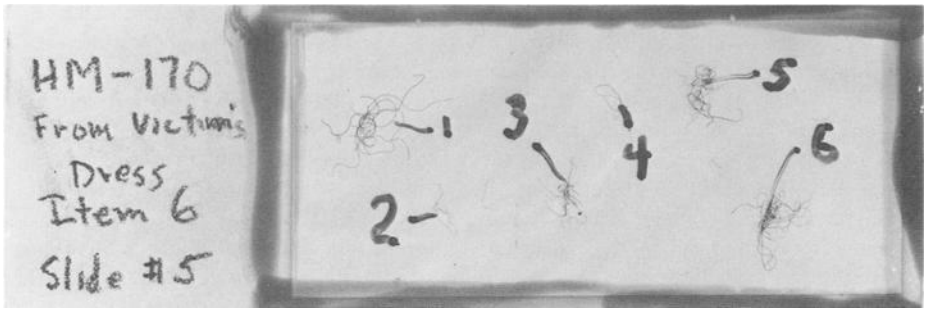

FIG. 2—*Microscope slide ready for identification and comparison of recovered and segregated fibers.*

The fiber type is identified by using a previously described method [*2*]. Reference to this method will make clear the basis for using Cargille H.D. refractive index liquid $n_D^{25} = 1.525$ as the mounting medium.

The fiber is then characterized, with appropriate recordings into case notes, in terms of color, value, width, uniformity of diameter, presence or absence of delustrant particles, size and distribution of delustrant particles when present, presence or absence of prominent striae, and presence or absence of regular angular effects along the length. A drawing can replace much of the verbal description and can be done with rapidity and to approximate relative scale from fiber to fiber.

Systematization of the information recorded expedites searches when intercomparison of many like fibers from several different sources must be performed. A columnar method can be used in cases of relatively low complexity. A card system allowing sorting has been found to be useful in highly complex cases.

Under favorable circumstances, the process of identification and characterization leads readily to the finding of indistinguishable fibers from two or more sources. When circumstances are unfavorable, reference is made to the catalogued notes for fibers from different sources, which descriptively qualify for direct comparison. Those fibers qualifying are retrieved for direct microscopic comparison through reference to slide and fiber number assignments.

Comparisons

Comparisons are effected at an approximate ×100 magnification with a good quality microscope. A comparison microscope can be used but is not essential.

Fibers on a slide from a source are found through their line-marked numerical designations and examined critically for all useful comparison features. Comparisons against fibers of similar description, but from another source, are done through rapid interposition of the two slides. The ability to compare the directly viewed fiber with the retained mental image of another fiber is sufficient in virtually all instances. Furthermore, the method has the advantage of allowing fibers from the two or more sources to be compared under identical lighting and conditions.

Fibers that are descriptively similar, but in truth dissimilar, are readily seen as different when subjected to direct microscopic comparison, and no further consideration needs to be given. If differences are not apparent, the fibers are critically compared to discern and assess any fine differences. If none are found, or if the fine differences can be accounted for with objective reasoning, it can be concluded that the fibers match. The term *match* is used in the sense that one fiber is the microscopic counterpart of another.

Photographic Recording

Recording of fiber matches is important for the record and for possible use at a judicial proceeding. Today's technology enables this step to be performed inexpensively and rapidly.

The photomicrographic system used by the author includes an Olympus OM-2N SLR camera and photomicrographic accessories available for this camera: eyepiece adapter, adapter L for attachment to the camera, Vari-Magni Finder, and OM-System Focusing Screen No. 1-12. The microscope used is a Model POS Olympus Polarizing Microscope. A ×10 strain-free objective (numerical aperture (NA) = 0.25) and a P7X ocular, both Olympus, can be used to give an approximate ×35 magnification onto the film plane. A high-intensity light source, Olympus LSD, mounted on a table stand and a continuously variable low voltage transformer with voltmeter completes the equipment required.

The automatic exposure control system of the camera—through the lens, off the film plane sensing of the light intensity—enables rapid and highly reproducible exposures. Photomicrographic exposures of all fiber matches should be performed on the same roll of film under the same conditions, to preserve the validity of the comparison. One of the exposures should be of a stage micrometer scale.

Kohler illumination should be used. The procedure for obtaining this kind of illumination is given in detail by McCrone and Delly [*3*].

The equipment described is relatively modest in cost, but has met the author's requirements for rapidity, resolution, reproducibility of exposure from frame to frame, and color rendition. Other systems can obviously be used to meet these requirements.

Discussion

The methods given were evolved through experience. Observations from casework, some of which have lead to improvement from the author's previous practices, are noted as follows.

Adhesive rollings

The adhesive rollings are very effective for recovery of fibers from clothing articles, bedding, fabric covered seats, most carpets, and like articles; the principal characteristic determining the effectiveness of transfer is the tightness of weave of the article. Difficulties were experienced with deep-fibered articles such as fur coats and deep pile rugs.

The principal advantages of the adhesive rolling method over the method of vacuum sweeping for recovery of fibers are the savings in time, avoidance of dust, ease of search, and convenience in storing the rollings. An additional advantage is that, in favorable instances, clusters of fibers representing several types of fibers and colors are transferred to the adhesive as clusters and remain as such despite continued rolling of the article surface.

Edge Sealant

An alternative cover slip edge sealant using Paraplast®, described in Ref *2*, is limited in effectiveness to approximately three to five weeks, after which apparent increases in the refractive index of the fibers take place. Such changes were evident from the dispersion staining colors seen. Replacement with fresh Cargille H.D. refractive index liquid, $n_D^{25} = 1.525$, restored the correct colors. The changes are to be attributed to preferential loss of the high refractive index component of the immersion liquid by slow diffusive migration through the seal.

The modified sealant described in this article is substantially superior in strength and imperviousness to the effects of the immersion liquid and adhesion. This improved sealant has

been tested on glass particles and fibers of known refractive index. No changes have been noted in up to six weeks, the time of this writing.

Rapid Identification

Identification of hundreds of synthetic textile fibers has been effected by using the single liquid mount method. A variety of fiber encountered but not included in the method was subsequently identified as Vinyon (poly[vinyl chloride] [PVC]). The fibers composed the colorless lining of long underwear worn by a police officer accused of committing a sex offense during his duty hours.

Dispersion staining colors for Vinyon (PVC) in Cargille H.D. liquid $n_D^{25} = 1.525$ are: orange for $n_\parallel (n_D = 1.541)$, red orange for $n_\perp (n_D = 1.536)$. Birefringence is low and the sign of elongation is positive.

Vinyon HH, which was included in the method, has never been encountered, and for practical purposes can be excluded from consideration, since production of this synthetic fiber has been discontinued since about 1950.

Heavily dyed purplish blue polyester fibers were seen to have reddish orange to red central stop dispersion staining colors. Such edge color effects are inconsistent with any of the color effects previously described. They are believed to be attributable to the intensity of dyeing. The fibers were identified without difficulty through consideration of other properties: very high birefringence, absence of interference orders between crossed polars, prominent dark edge effects for $n_\parallel$, and barely discernible edge effects for $n_\perp$ with either the normal aperture or the annular stop of the dispersion staining objective. This particular problem illustrates the value of making all observations before coming to a conclusion.

Discovering the Unseen

In a homicide by stabbing, a jackknife was recovered from its hiding place through information provided by an informant. The jackknife was linked to the suspect and victim through fibers: a single colorless triacetate fiber from the knife blade was matched by colorless Arnel® triacetate fibers from the jogging suit of the victim; three different colored acetate fibers from the well of the jackknife were found to be the same in color as acetate fibers from the suspect's jacket lining. Noteworthy is the failure to find the single fiber on the blade of the jackknife during the initial examination under a stereoscopic microscope. Reexamination by varying the angle of incident lighting revealed the colorless triacetate fiber plastered flat on the blade surface. The acetate fibers were recovered by scraping the debris from the well with a toothpick.

Observations Drawn from Casework

The necessity of interpreting evidentiary worth is the natural consequence of fiber matching. Some observations drawn from several significant cases occurring in the past eight years that bear upon this problem follow.

Fiber Types Encountered

It is roughly estimated that 75% of all adherent fibers recovered for study from case articles are either nylon or acrylic. Nylon fibers seen are usually those having the microscopic characteristics of Dupont's Antron® or Type 501 fiber. The cross-sectional trilobal characteristics of these fibers can be deduced from their appearance as presented by a longitudinally mounted fiber.

Adherent polyester fibers such as Dacron® are not as common as might be expected from their frequency of usage. An explanation for this is that polyester fibers are normally found in smooth, tightly woven fabrics that do not shed fibers readily. Cotton and wool are infrequent, especially wool.

Wide Diversity of Comparison Features

The principal basis for differentiating fibers identified as the same type is color and shade of color. When present, delustrant particles—their size, uniformity of size, and distribution—can have exceptional value for differentiation because of their high reproducibility among fibers from the same source. Both color and delustrant particle characteristics vary widely in synthetic fibers of the same type but known to be from different sources. The validity of this observation is best appreciated after gaining experience in examining fibers from many sources. An interesting and informative exercise is to sample fibers from a common usage source such as one's own rug and then to attempt to find their microscopic counterparts in adherent fibers found on articles encountered in casework. It will be apparent that there are few, if any, fibers that can be said to be "common."

Effects of Transformations in Fibers and Dye Technology

The low frequency of occurrence of natural fibers, together with the multiplicity in colors and other comparison features encountered, represent a marked change from the author's early work experience. This should be no surprise considering the interim of time involved—approaching 30 years—and the great transformations in fibers and dye technology that have taken place during this time. The surprise has been the extent of the change, the early work experience being that cotton and wool were found in overwhelming abundance relative to synthetic fibers and in a much narrower range of colors and shades of color than those seen currently. Today's forensic scientist does not need to ponder long to grasp the implication of these transformations.

Case Illustrations

Two cases will serve to emphasize the value of fibers as evidence. In each of the two cases, matching fibers stood virtually alone as the principal investigative evidence developed against the defendant.

Case 1

During September 1974, a four-year-old girl disappeared from her neighborhood in San Jose, California. Her body was found eleven days later. Four significant fibers, by color and type, were recovered from the victim's two-piece playsuit. A 16-year-old youth was developed as a suspect through the tracing of an obscene telephone call during which sexually explicit references to the victim were made. Examination of the suspect's bedroom rug resulted in the recovery of fibers that were the microscopic counterparts of the four found on the victim's playsuit. Principal among those found were orange wool fibers. These proved to be ubiquitous to the suspect's household, its occupants and their vehicles. Matching orange wool fibers were found on the rear deck of a Volkswagen station wagon, which was investigatively established as having been stolen by the suspect two days before the victim's disappearance and abandoned at an accident scene two days after.

The suspect was arrested and charged with kidnap, rape, and murder. He was found guilty on all charges.

Case 2

During June of 1980 the body of a partially clothed young black woman was found alongside a levee road paralleling a major expressway in San Jose, California. Early police investigations produced no results. Twenty months later, investigative attention was drawn towards a suspect in a series of eight San Francisco Bay area murders occurring during the period of 1972 to 1980. These murders all bore the same earmarks: black female victims who were young and partially clad or nude, no attempt to hide the body, and death by strangulation. All were unsolved.

A sofa bed was brought to the laboratory. It was from the residence of the suspect's estranged wife and had been placed through investigation in the suspect's Dodge van during a period of time that included the day the body was discovered in San Jose.

Fiber examinations resulted in five fiber matches between fibers from the victim's clothing and fibers from the sofa bed. All were synthetic fibers. Later, the Dodge van, which had been sold by the suspect, was located. The van and clothing from the body of a 1978 San Francisco victim were brought to the laboratory for examinations. Nylon fibers recovered from the 1978 victim's clothing were found to be the microscopic counterparts of nylon fibers from the rug in the van. A nylon fiber matching fibers from these two sources was found on adhesive rollings from the sofa bed. Finally, one of the five fiber matches previously shown was repeated with a matching fiber from a location on the rug which had been protected from wear by furniture in the van.

The five fiber matches established proof beyond reasonable doubt that prior contact had taken place between the suspect's sofa bed and the San Jose victim's clothing. The fiber match between fibers composing the rug in the suspect's van and adherent fibers recovered from the San Francisco victim's clothing effectively linked the two cases.

Conclusions and Remarks

The examination methods described have been proved by case experience to offer substantial advantages over methods described by Kirk [*1*]. The rapidity of examination afforded, together with the widely expanded range of comparison features resulting from transformations in fibers and dye technology, can lead to a clear conclusion: under favorable circumstances, today's forensic scientist can achieve gratifying results in casework by applying attention to fibers.

It is believed that the results produced from casework represent a vindication of the visionary earlier work of Kirk [*4,5*] and a refutation of the disparagement given to this variety of evidence by Houts [*6*].

The author is aware that the methods of examination described can be improved upon, that the observations given require confirmation through systematic study, and that there have been imperfections in the planning and execution of this article. Nevertheless, it is hoped the article will be useful, especially since it contains material not to be found in the recent forensic science literature.

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