Fiber Identification and Comparison

1. Scope

This procedure outlines the collection, examination, identification and comparison of fiber evidence (including fabric and ropes). Typically, fiber examinations involve a comparison of samples from a known, with questioned fibers to determine whether they are consistent with having originated from the same source. Other polymeric materials may also be identified and compared using this procedure.

Forensic examination and comparison of fabrics/carpets and cordage include documentation of various physical characteristics. The evidence is evaluated to the point of fiber type unless a physical match can be obtained.

2. Terms and Definitions

Delustrant – A pigment, usually titanium dioxide, used to dull the luster of a manufactured fiber.

Birefringence – The numerical difference between the parallel refractive index and the perpendicular refractive index.

Refractive Index – The ratio of speed of light in a vacuum to the speed of light in a medium.

Morphology - General description of shape, texture and size.

Targeted sampling - fibers are selected for further examination based upon certain characteristics they have in common with a potential source (e.g., mounting only red trilobal carpet-type fibers from the victim's evidence given the suspect has red carpet as a possible source).

Manufactured fiber - A class name for various families of fibers produced from fiber-forming substances which may be synthesized polymers, modified or transformed natural polymers and glass.

Natural fiber - A class name of fibers of vegetable origin (e.g., cotton, flax, ramie), animal origin (e.g., silk, wool, and specialty furs) or of mineral origin (e.g., asbestos).

Becke Line Method - A method for determining the refractive index of a fiber relative to its mountant by noting the direction in which the Becke line moves when the focus is changed. The Becke line will always move toward the higher refractive index medium (fiber or mountant) when focus is raised and will move toward the lower refractive index medium when focus is lowered.

Comparison polarized microscope - A system of two microscopes positioned side-by-side and connected via an optical bridge in which specimens may be examined simultaneously in the field of view in transmitted or polarizing light.

3. References

J. Gordon Cook, Handbook of Textile Fibers, Volume 1, Natural Fibers, Merrow, 1984.

J Gordon Cook, Handbook of Textile Fibers, Volume 2, Man Made Fibers, Merrow, 1984.

James Robertson, Forensic Examination of Fibers, Ellis Horwood Limited, 1992.

Max M. Houck and Jay A. Siegel, Fundamentals of Forensic Science, Elsevier Academic Press, 2006.

Identification of Textile Materials, 7th Edition, The Textile Institute, Manchester, 1975.

Nicholas Petraco and Thomas Kubic, Color Atlas and Manual of Microscopy for Criminalistics, Chemists and Conservators, CRC Press, 2004.

4. Examination Procedures

4.1. Evidence Types

This evidence can include, but is not limited to: victim's clothing, subject's clothing, carpet and fabric standards from the crime scene, vehicle or from the victim's or subject's environments. Additionally, cordage, fabrics and carpet pieces can be included.

4.2. Instruments and Equipment

Petri Dishes
Metal Spatula
Clean Catch Paper
Forceps
Microscope Slides
Cover Slips
Fourier Transform Infrared Spectrometer with Microscope (FTIR)
Pellet press and die

Mettler Hot Stage/Polarizing Light Microscope
Polarizing Light Comparison Microscope
Stereomicroscope
Photographic Equipment with accessories
Fiber Microtome
Calipers
Rulers

4.3. Reagents and Chemicals

Permount™ Mounting Media
Xylene

These are not critical reagents or chemicals. Permount may be used beyond the expiration date as long as it has not yellowed and continues to "flow" properly. This will be determined by the examiner.

4.4. Procedural and Chemical Precautions

Refer to the TBI Safety Manual for general safety requirements and hazard information regarding the use of reagents and solvents, and overall safety guidelines.

Protective attire, including laboratory coat, mask, gloves and eye protection should be used when working with clothing and/or bloodstained items.

Decontamination of a scientist's work area should be performed after each use, but shall be done after analyzing bloodstained items.

As a precaution for contamination issues: Subject and victim's items cannot be in an open condition at the same time or in the same work area until debris is collected. The subject's clothing will be scraped in the subject scraping room and debris collected. The victim's clothing will be scraped in the victim's scraping room with debris being collected. Lab coats and gloves will be changed between processing of subject and victim items. The scraping room tables will be cleaned before and after debris collection. Debris will be scanned and mounted on slides without the standards being in the microscope mounting area. All microscope slide mounting areas that will be used will be cleaned prior and after fibers are mounted.

4.5. Limitations

Comparison of cotton fibers may have a limited evidentiary value due to the frequent use of cotton in today's society.

4.6. Procedure

4.6.1. Debris collection

If evidence is being processed by other sections of the laboratory prior to fiber examination, it is requested that the examiner in that section work the item over catch paper. This catch paper will be placed inside the original packaging with the evidence.

Evidence items may be photographed as case file documentation.

Subject and victim's items cannot be in an open condition at the same time or in the same work area until debris is collected.

The examiner will wear lab coat, gloves, mask and eye protection during the scraping process.

Clean the scraping room tables before beginning scraping items.

Take unopened question fiber evidence into appropriate scraping room. Remove the item(s) of evidence from its original packaging and suspend the item(s) over clean catch paper.

The subject's item(s) will be scraped in the scraping room designated "subject". The victim's item(s) will be scraped in the scraping room designated "victim".

Scrape the item with a long spatula for a sufficient time to remove all potential fiber evidence onto the catch paper.

Debris may be removed from evidence with forceps, if scraping is not appropriate.

Return the item(s) to its original packaging.

Collect the debris and transfer to labeled petri dish.

Lab coats and gloves will be changed between processing of subject and victim items.

Clean scraping room table after completion of debris collection.

Repeat the procedure for the known fiber evidence. Fiber evidence collection from different individuals shall occur on separate days in different scraping rooms. Known fiber samples may be collected without scraping the items.

4.6.2. Stereomicroscope

Petri dishes containing question and known fibers shall not be opened at the same time in the same area.

Clean the area under and surrounding the stereomicroscope.

Place petri dish containing known fiber standards under stereomicroscope and observe color of the known fiber standards. Document observations in case notes.

Mount known standard fibers by taking a random representative sample of fibers that include all colors represented in the known fabric or fiber source, onto a clean glass microscope slide using mounting media and cover slip.

Remove known fiber petri dishes from area and clean the area under and surrounding the stereomicroscope.

Place petri dish containing debris from question item(s) under stereomicroscope. Scan for fibers similar to the fibers in known standards (targeted sampling). Document observations of color of possible question fibers.

Mount question fibers with similar features to known standards on a clean glass microscope slide using mounting media and cover slip.

Clean the area under and surrounding the stereomicroscope once fiber mounting is complete.

Once fibers are mounted onto slides, question and known slides may be maintained in the same area.

4.6.3. Polarizing Light Comparison Microscope

Scan question slides for fibers suitable for comparison to known fibers. Document the location on the slide and the characteristics observed for each fiber observed in case notes.

Scan the known slides and observe the characteristics of the known fibers. Document the location on the slide and the characteristics observed in case notes. If large bundles of like fibers are being analyze then documentation of the location is not necessary.

It is recommended that in cases with a large volume of debris to re-scan question petri dishes two additional times to collect all possible fiber evidence. Additional slides prepared from these collections will be scanned as above and documented in case notes.

All question and known fibers with similar characteristics are examined side-by-side and documented on a Fiber Comparison Worksheet. The optical properties examined and documented should include, but are not limited to:

Color
Shape
Size
Delusterant (none – heavy)
Refractive index ($\parallel$, $\perp$, to Permount)
Extinction positions
Birefringence colors

4.6.4. Fourier Transfer Infrared Spectrometer with Microscope (FTIR)

Prepare the instrument by acquiring a spectrum of a polystyrene standard for each day of case analysis and retain in the case file. Observe the following peak wavenumbers: 3082, 3060, 2849, 1943, 1601, 1028 and 906. The bands will not vary more than +/- 2 wavenumbers.

Break cover slip over question fiber, remove a small portion of the fiber and clean with xylene. Allow the xylene to evaporate.

Flatten the fiber using pellet press and die.

Prepare a microscope sample holder by placing a small piece of cellophane tape over one half of hole. Transfer the flattened fiber to the tape so that the fiber hangs over the edge of the tape.

Repeat for known fibers.

Place the sample holder under the FTIR microscope and image the sample.

Acquire a minimum of 50 scans for each sample analyzed and a minimum of 50 background scans. Other instrument parameters are printed on the spectrum printout.

Compare the question spectrum with reference spectra from the polymer library for determination of polymer type. Compare by overlaying the spectra and examining peak position and relative peak intensities. If there are no meaningful differences between the spectra, then the polymer type is identified. If meaningful differences are noted, then further analysis may be necessary.

Obtain spectra for both the question and known fibers. Compare by overlaying the spectra and examining peak position and relative peak intensities. If there are no meaningful differences between the spectra, then the question and known are consistent. If meaningful differences are noted, then the question and known are inconsistent.

Retain the acquired spectra as part of the case file notes.

4.6.5. Additional testing (if applicable)

4.6.5.1. Cross Sectioning

If sample quantity allows, cross sections of the question and known fibers can be made and compared. The fiber sample to be sectioned is placed into the grooves of the fiber microtome and secured. The protruding fibers are sliced off flush with the microtome with a scalpel or razor blade. The dial that raises the fibers is rotated into position. A small amount of clear mounting medium is applied to the exposed fiber ends. Once hardened, the fiber ends are sliced off with a scalpel or razor blade and mounted on a microscope slide for observation and comparison.

4.6.5.2. Melting Point of Nylon Fibers

If the forensic scientist deems it relative and sample quantity is sufficient, the melting point of the question and known nylon fibers can be determined.
Samples of the question fiber, known fiber and a reference nylon fiber/polymer are dry mounted between a slide and cover slip. The reference nylon slide is placed in the Mettler hot stage attached to a polarizing light microscope. The hot stage controller begins to heat the sample which is observed through the microscope. The temperature is recorded when the sample first begins to melt. The temperature is also recorded when no further change occurs to the sample. The hot stage controller then cools the stage back to its starting temperature. The procedure is repeated for the question fiber and the known fiber. The reference nylon fiber/polymer temperature range shall fall within published ranges for the particular nylon type. The question and known fibers' temperature ranges should overlap each other and fall within published ranges for the particular nylon type represented in the question and known.

4.6.6. Fabric/Carpet Comparisons

Occasionally fabrics are requested to be compared. If a fracture match is not possible then the physical characteristics are examined and compared. Fabric examinations are primarily a process of deconstructing the fabric by dissecting its constituent elements. Each of these elements can have a number of sub-elements, all of which may be characterized. These elements may include:

Construction (woven, knit, non-woven)
Threads per inch in warp and weft direction
All fiber types composing the fabric
Number of plies
Color(s) and design
Direction of twist of plies
Number of filaments in each ply
Sewing threads, buttons, decorations, etc. detailed as above

The process of deconstructing the fabric and identifying the elements and sub-elements should be documented using photographs, micrographs, and/or case notes. If any meaningful differences are observed between the question and known fabric or carpet constructions, the analysis will be discontinued.

When no significant differences are observed, fibers are collected from the question and known fabric/carpet and compared following the fiber comparison procedure.

4.6.7. Ropes and Cordage

The initial step in the identification of rope and cordage is to determine its construction and assembly. These characteristics may include, but are not limited to:

Knots (leave intact)
Color(s)
Diameter
Condition of ends (i.e. cut, frayed, burned)
Staple or filament fibers
Twisted, braided, or non-twisted
Number of strands
Number of filaments in each ply or braid
Core or tracers, if any
Coatings, if any

Document all construction and assembly characteristics using photographs, micrographs, and/or case notes. If any meaningful differences in the construction and assembly are observed between the question and known rope/cordage, the analysis will be discontinued. When no meaningful differences are observed, fibers are collected from the question and known rope/cordage and compared following the fiber comparison procedure.

Additional characteristics may be used if necessary to adequately describe the cordage.

5. Measurement Traceability

Measurements are occasionally conducted, (i.e. length, width and diameter) in fiber examinations and comparisons to establish the range of characteristics present in a sample of fibers. The uncertainty of these measurements does not have a significant effect on the outcome of the analysis, as the measurements are used for comparative purposes only.

6. Reference Materials

Reference Collection of Synthetic Fibers, Collaborative Testing Services, Inc., May 1986.

SP^2 Scientific Products, Polymer Sample Kit

NIST traceable polystyrene standard

TBI Crime Laboratory Fiber Reference Collection (slides and bulk samples)

Synthetic Fibers by Microscope (Sadtler) (FTIR)

TBI fiber library (FTIR)

The reference collections mentioned above are maintained in the Microanalysis section. These collections will be used for training and may be used for reference purposes. The collections may be in the form of data, mounted slides or bulk fibers. If the samples will be used for reference purposes, the slides and samples will be identified and documented. The collection shall be maintained in a location that protects it from contamination and from alteration.

7. Reports

The following are possible results concluded from the examination:

Physical and microscopic comparison of (the fiber type) fibers from exhibit ____ with (the fiber type) fibers in the construction of exhibit ____ revealed them to be consistent with respect to optical properties, color and fiber type(s). Therefore, these fibers in exhibit ____ could have come from exhibit ____ or another source consistent with these properties.

Physical and microscopic comparison of fibers from exhibit ____ with fibers in the construction of exhibit ____ revealed them to be inconsistent with respect to ____. Therefore, these fibers in exhibit ___ could not have come from exhibit ____.

Physical and microscopic comparison did not reveal the presence of fibers to indicate a fiber transfer.

Physical, microscopic and instrumental comparison of (the fiber type) fibers from exhibit ____ with (the fiber type) fibers in the construction of exhibit ____ revealed them to be consistent with respect to optical properties, color and fiber type(s). Therefore, these fibers in exhibit ____ could have come from exhibit ____ or another source consistent with these properties.

Physical, microscopic and instrumental comparison of fibers from exhibit ____ with fibers in the construction of exhibit ____ revealed them to be inconsistent with respect to ____. Therefore, these fibers in exhibit ___ could not have come from exhibit ____.

Due to ____, the physical and microscopic comparison of exhibits ___ is inconclusive.

Physical and microscopic comparison of the cotton fibers in exhibit_____with cotton fibers in exhibit _____ revealed them to be consistent with respect to color and appearance. Therefore, the cotton fibers in exhibit ___ could have come from exhibit _____ or other sources with these properties.

Due to the frequent use of cotton in today's society, comparison of cotton fibers may have a limited evidentiary value.

Physical and microscopic comparison of fabric from exhibit____with fabric in exhibit ___ revealed them to be consistent with respect to color, construction and composition. Therefore, exhibit ___ could have a common origin with exhibit ___ or another source with these same physical properties.

Physical and microscopic comparison of the rope from exhibit____with the rope in exhibit ___ revealed them to be consistent with respect to color, construction and composition. Therefore, exhibit ___ could have a common origin with exhibit ___ or another source with these same physical properties.

Physical microscopic and instrumental comparison of fabric from exhibit____with fabric in exhibit ___ revealed them to be consistent with respect to color, construction and composition. Therefore, exhibit ___ could have a common origin with exhibit ___ or another source with these same physical properties.