Standard Guide for Forensic Examination and Comparison of Pressure Sensitive Tapes

Materials (Trace) Subcommittee
Chemistry/Instrumental Analysis Scientific Area Committee
Organization of Scientific Area Committees (OSAC) for Forensic Science

OSAC Proposed Standard

Standard Guide for Forensic Examination and Comparison of Pressure Sensitive Tapes

Prepared by
Materials (Trace) Subcommittee
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Disclaimer:

This document has been developed by the Materials (Trace) Subcommittee of the Organization of Scientific Area Committees (OSAC) for Forensic Science through a consensus process and is *proposed* for further development through a Standard Developing Organization (SDO). This document is being made available so that the forensic science community and interested parties can consider the recommendations of the OSAC pertaining to applicable forensic science practices. The document was developed with input from experts in a broad array of forensic science disciplines as well as scientific research, measurement science, statistics, law, and policy.

This document has not been published by a SDO. Its contents are subject to change during the standards development process. All interested groups or individuals are strongly encouraged to submit comments on this proposed document during the open comment period administered by ASTM International (www.astm.org).

Date: **March 2020**

To: **Subcommittee E30.01 members**

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Ballot Action: **Proposed new standard**

Rationale: The OSAC Materials (Trace) Subcommittee has developed an overarching guide for the forensic analysis of tapes. This document was created through a consensus process. It is anticipated that the standard will be used by practitioners and laboratories for use in developing an analytical scheme for the forensic analysis of tape. Legal or scientific terms that are generally understood or defined adequately in other readily available sources are not be included in this standard. The negatives received during the prior balloting have been adjudicated and this new standard guide is ready for re-balloting.

Standard Guide for Forensic Examination and Comparison of Pressure Sensitive Tapes

1. Scope

1.1 This guide is intended as an introduction to other standard guides for the forensic examination of pressure sensitive adhesive tape. It is intended to assist individuals who conduct forensic tape analyses in their evaluation, selection, and application of tests that can be of value to their examinations. This guide describes the construction and classification of various tapes and the methods to develop discriminatory information using an efficient order of testing. However, it is not intended as a detailed method's description or rigid scheme for the analysis and comparison of tapes, but as a guide to the strengths and limitations of each analytical method. The goal is to provide a consistent approach to forensic tape analysis.

1.2 The forensic tape examiner addresses concerns such as sample size, complexity and condition of the sample, environmental effects, collection and packaging methods, and case / investigation specific issues. These factors require that the forensic tape examiner choose test methods, sample preparation schemes, testing sequences, and degree of sample alteration and consumption that are suitable to each specific case.

1.3 This standard cannot replace knowledge, skills, or abilities acquired through education, training, and experience (E2917), and is to be used in conjunction with professional judgment by individuals with such discipline-specific knowledge, skills, and abilities.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *Some of the methods discussed in this guide involve the use of chemicals, temperatures, and radiation sources. This guide does not purport to address the possible safety hazards or precautions associated with its application. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory requirements prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision of Principles for the Development of International Standards issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Reference Documents

2.1 *ASTM Standards:*

D123 Terminology Relating to Textiles

E1492 Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Laboratory

E1732 Terminology Relating to Forensic Science

E2224 Guide for Forensic Analysis of Fibers by Infrared Spectroscopy

E2225 Guide for Forensic Examination of Fabrics and Cordage

E2228 Guide for the Microscopical Examination of Fibers

E2917 Standard Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Programs

E3085 Guide for Using FTIR in Forensic Tape Examinations

E3233 Standard Practice for a Forensic Tape Analysis Training Program

2.2 *Other Documents:*

SWGMAT Guideline for Assessing Physical Characteristics in Forensic Tape Examinations
SWGMAT Guideline for Using Light Microscopy in Forensic Tape Examinations
SWGMAT Guideline for Using Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy in Forensic Tape Examinations
SWGMAT Guideline for Using Pyrolysis-Gas Chromatography and Pyrolysis-Gas Chromatography/Mass Spectrometry in Forensic Tape Examinations

3. Terminology

3.1 Definitions – For additional terms commonly employed for general forensic examinations, see E1732.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adhesive:* A material that holds two or more objects together solely by intimate surface contact.

3.2.2 *additives:* Materials that are included in adhesive or backing formulations to increase overall volume, impart color, or provide other desired properties.

3.2.3 *backing:* A thin flexible material to which adhesive is applied.

3.2.4 *backsize:* A layer applied to the top side of the backing. Its purpose is to coat and fill a porous surfaced backing with a material that is inert to the adhesive formulation to be used.

3.2.5 *biaxially oriented polypropylene (BOPP):* An oriented polypropylene film in which the polymer has been stretched in both the machine direction and cross direction during the manufacturing process. Tapes with such films cannot be torn by hand.

3.2.6 *calendering:* A method of producing adhesive tape by pressing an adhesive to a backing material through a series of heated rollers. The surface appearance depends on the type of roller used.

3.2.7 *calendering marks:* Characteristic marks left on the backing material due to the manufacturing process.

3.2.8 *cellophane:* A thin, transparent sheet made of regenerated cellulose that can be used as a backing material in tape products.

3.2.9 *cellulose acetate:* A type of transparent film that is used for tape backings.

3.2.9.1 A matte surface is used for write-on tapes. Cellulose acetate is more moisture-resistant than cellophane.

3.2.10 *creped paper:* Paper that has small folds in it giving it high stretch and conformability. Used in the backing of masking tape (saturated paper tape).

3.2.11 *elastomer:* A material that can be deformed but when the forces are removed it returns to its original form. Serves as the base material for pressure sensitive adhesives.

3.2.12 *exclusionary difference:* A difference in a feature or property between compared items that is substantial enough to conclude that they did not originate from the same source.

3.2.12.1. An exclusionary difference is statistically supported when an appropriate statistical analysis shows a result outside the range of what usually occurs when the items originate from the same source.

3.2.12.2. When a statistical analysis is not suitable, an exclusionary difference can be determined by expert judgment.

3.2.13 *fill yarns:* See weft yarns (filling)

3.2.14 *flatback paper:* Smooth paper backing masking tape (saturated paper tape).

3.2.15 *machine direction:* The direction of the tape that runs the length of the tape.

3.2.16 *migration:* The movement over a period of time of an ingredient from one layer to another.

3.2.16.1 This often occurs in electrical tapes where plasticizer in the polyvinyl chloride (PVC) backing "migrates" into the adhesive.

3.2.17 *monoaxially oriented polypropylene (MOPP):* An oriented polypropylene film in which the polymer has been stretched in only one direction during the manufacturing process. Tapes with such films can be torn by hand.

3.2.18 *plasticizer:* Material added to plastics to impart flexibility by creating spaces between the polymer chains and lowering the inter- and intra-chain attractive forces, allowing freer movement of the chains.

3.2.18.1 Plasticizers are used in pressure sensitive backings (particularly PVC) and some adhesives to lower the glass-transition temperature and allow use at sub-ambient temperatures.

3.2.19 *pressure sensitive adhesive (PSA):* An adhesive that consists of a polymeric base, usually with appropriate plasticizers and tackifiers. It can form an adhesive bond with no physical or chemical change and with the application of only slight pressure.

3.2.20 *pressure sensitive adhesive (PSA) tape:* A combination of a pressure sensitive adhesive with a continuous flexible backing (cloth, paper, metal, or plastic) or with a backing and release liner.

3.2.20.1 Use of the word "tape" in this guide refers to PSA tapes and their components.

3.2.21 *prime coat:* A coating of adhesive-like material found between the tape adhesive and backing that serves as a bonding agent.

3.2.22 *reinforcement:* Fabric (scrim), glass filaments, or plastic filaments added to tape to impart stability and strength.

3.2.23 *release coat:* A coating applied to the top side of the backing that provides ease of unwind and prevents delamination or tearing.

3.2.24 *scrim:* A loosely-woven gauze-type fabric added to duct tape for reinforcement and to impart strength.

3.2.25 *scrim count:* The number of warp yarns per inch versus the number of fill yarns per inch.

3.2.26 *tack:* Property of an adhesive that allows it to form a bond immediately with a surface with the application of only slight pressure.

3.2.27 *tackifier:* Low molecular weight organic material that is added to the adhesive base polymer to impart tack.

3.2.28 *thickness:* Distance from one surface of a tape, backing, or adhesive to the other, usually expressed in mils or thousandths of an inch.

3.2.29 *warp:* The yarn running lengthwise in a woven fabric (D123).

3.2.29.1 Warp fibers in a scrim fabric run lengthwise in the machine direction of a reinforced tape.

3.2.30 *weft:* The yarn running from selvage to selvage at right angles to the warp.

3.2.30.1 Weft yarns run crosswise, perpendicular to the warp direction in the scrim fabric of reinforced tape. Also known as fill yarns.

3.2.31 *yarn:* A generic term for a continuous strand of textile fibers, filaments, or material in a form suitable for knitting, weaving, or otherwise intertwining to form a textile fabric (D123).

3.2.31.1 For the purposes of this guide, yarn refers to lengths of fiber reinforcement (e.g., twisted staple fibers, filament fibers).

4. Quality Assurance Considerations

4.1 A quality assurance program shall be used to ensure that analytical testing procedures and reporting of results are monitored by means that include but are not limited to proficiency tests and technical audits. General quality assurance guidelines are found in "Trace Evidence Quality Assurance Guidelines" (1).

5. Summary of Guide

5.1 The analysis and comparison of tape evidence in the forensic science laboratory can provide valuable information due to the variability of tape products. However, some classes of tape exhibit more variability between sources than others. In general, the more complex the product (e.g., duct tape), the more features it has for comparison lending itself to higher discrimination.

5.2 This guide provides an overview of techniques applied to the forensic analysis of tape components. The information contained herein is intended to assist the examiner in characterizing and comparing evidentiary tape samples. The forensic examination of tape encompasses the determination of physical construction and chemical composition of tape products. General information on product variability, construction, and composition is provided.

5.3 While tapes within a specific class can appear similar on a macroscopic level, differences can be found on further examination of the physical and chemical characteristics. Methods for the analysis of tape include the examination of physical characteristics, polarized light microscopy (PLM), Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, pyrolysis gas chromatography/mass spectrometry (PGC-MS), scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS), X-ray fluorescence spectrometry (XRF), X-ray diffraction (XRD), microspectrophotometry (MSP), and laser ablation inductively coupled mass spectrometry (LA-ICPMS). These different techniques can provide complementary information and should be selected and employed in an order to obtain the most discriminating information consistent with the laboratory's capabilities.

5.4 Typically, a tape examination involves searching for and assessing any differences in the comparison of questioned and known samples. The absence of exclusionary differences at the conclusion of an analysis suggests that the tape samples could share a common origin. The strength of the interpretation is a function of the type or number of corresponding features, or both. The evaluation of tapes for class characteristics can associate known and questioned tapes to a group but not to a single, individual source. A physical fit of two tape ends could provide individualizing characteristics providing the highest degree of association between two tapes.

5.5 Questioned tape samples can also be submitted with a request to identify possible product information, manufacturer, and retailing sources, in an attempt to obtain investigative lead information. Physical characteristics and compositional data, collected as described in this guide, can be used in technical inquiries to tape manufacturing companies, comparisons with various brands of tape purchased at local commercial outlets, and for comparisons to samples in reference collections/databases.

6. Significance and Use

This guide is designed to assist the forensic tape examiner in selecting and organizing an analytical scheme for the analysis, comparison, and identification of tapes. The size and condition of the sample(s) influences the choice of analytical scheme. The evaluation and interpretation of the data for each technique is an important part of an analytical scheme but it is outside the scope of this document. These will be addressed in other ASTM Standards.

7. Sample Handling

7.1 The potential for a physical fit between known and questioned samples shall be considered before selecting the method of tape analysis. Care should be taken to preserve the ends of the tape samples for physical fit analysis.

7.2 Tape evidence can be a source for other trace evidence (e.g., hairs, fibers, paint, glass, and explosives), latent print evidence, and DNA evidence. Different forensic disciplines are often called upon to examine the same item of evidence. The order in which the examinations are conducted should be resolved on a case-by-case basis. If another discipline is chosen to examine the evidence prior to the tape examination, obtain an unaltered representative sample if possible.

7.3 Techniques to separate tape specimens should be chosen with care to minimize alterations in the chemical or physical properties. Methods for separation include using warm air, liquid nitrogen, or appropriate solvents (e.g., hexane, methanol).

7.4 The item of evidence should be preserved in a manner that does not interfere with future testing.

8. Tape Construction

8.1 Each of the components listed below might not be a part of all classes of tape. The relevant components are discussed under each individual tape class. The primary components of tape are the backing and the adhesive.

8.1.1 *Backings*

8.1.1.1 The tape backing, or film, provides a support material for the adhesive. There is a wide range of materials used for tape backings due to the vast number of commercial end uses for tape. These materials include, but are not limited to: polyethylene, polypropylene, polyvinyl chloride, saturated paper, cellulose acetate, cloth, and polyester.

8.1.1.2 The backing itself can be multi-layered.

8.1.1.3 Other materials that can be added to the backing include stabilizers, fillers, colorants, plasticizers, fire retardants and preservatives. Release coats, backsize, and primer coats can also be applied to the backing and are thin layers that are easily lost with use or can be difficult to separate and therefore are analyzed with the bulk of the backing material.

8.1.2 *Adhesives*

8.1.2.1 The formulation of PSAs consists of an elastomer to which tackifier resins and inorganic materials are added.

8.1.2.2 There are different elastomers used in PSAs. PSAs can contain one elastomer or a blend of several different elastomers.

8.1.2.3 Examples of elastomers used in PSAs include, but are not limited to: natural rubber (polyisoprene), synthetic polyisoprene, polybutadiene, polyisobutylene, styrene butadiene random copolymer, styrene isoprene block copolymer (SIS), styrene butadiene block copolymer (SBS), styrene ethylene-butylene block copolymer, ethyl or butyl acrylate, silicones, and neoprene.

8.1.2.4 Tackifying resins are blended with elastomers to lower the glass transition temperature, allowing freer movement of the polymer chains and thus giving PSAs their “sticky” adhesive property. The tackifying resin is typically a C-5 (five carbon hydrocarbon component). Silicone and acrylic PSAs do not require a tackifier. More costly silicone-based adhesives can be found in adhesive formulations of tapes that are manufactured for use in high temperatures or for chemical resistance.

8.1.2.5 Inorganic materials are added to an adhesive formulation to either increase the overall volume or to impart color. Such materials include calcite, dolomite, iron oxide, kaolinite, talc, titanium dioxide (rutile or anatase), and zincite. In addition, zincite can also function as an "accelerator," or cross-linker, for rubber-based adhesives.

8.1.2.6 The adhesive can also be multi-layered.

8.1.3 *Reinforcing Materials*

Reinforcing materials provide additional strength to the tape. The materials used for the reinforcement can include fabric (scrim) and glass or plastic filaments.

9. Tape Classifications

9.1 The classes of tapes most frequently encountered within forensic casework are duct tape, electrical tape, and packaging tape. There are numerous other types of tape that are less frequently encountered in case work.

9.1.1 *Duct tape*

9.1.1.1 Duct tape, also referred to as poly-coated cloth tape, consists of three basic components: the backing, the reinforcement fabric, and the PSA. These components together determine a duct tape's appearance, strength, and end use.

9.1.1.2 The backing, which is usually polyethylene, is available in various colors. Duct tapes that are silver or gray commonly contain a small amount of aluminum to impart color. Other colors are created by adding colored pellets to the molten polyethylene. Inorganic materials (e.g., talc or calcite) can be added to the backing to increase properties such as water repellency, tear strength, and opacity. The backing can consist of a single layer or multiple layers of polyethylene. The backing can also exhibit characteristics imparted during the manufacturing process, such as calendering marks and striations. Additionally, lettering or designs can be imparted onto the surface or underside of the polyethylene backing.

9.1.1.3 The adhesive formulation for duct tapes consists of an elastomer to which tackifying resins and inorganic materials are added. The elastomer is typically natural rubber (polyisoprene) but could also be a mixture/blend of synthetic or natural elastomers, or both. Other materials used as elastomers include styrene-butadiene copolymer and styrene-isoprene copolymer.

9.1.1.4 The tackifying resin is typically a C-5 (five carbon hydrocarbon) that is used to make the elastomer "sticky" or impart tack. Inorganic materials are added to an adhesive formulation to either increase the overall volume or to impart color. In duct tape adhesives, any of the following examples can be found: calcite, dolomite, kaolinite, talc, titanium dioxide (anatase or rutile), and zincite.

9.1.1.5 The reinforcement fabric in duct tape, known as scrim, is commonly constructed of cotton, polyester, or a blend of these two materials. Reprocessed cellulose can also be found. The scrim is generally manufactured as either a plain weave or weft-insertion (having knit warp yarns and texturized fill yarns). Woven yarns can be twisted (spun), texturized, or filament in both the warp and fill directions. Variations of these are also observed.

9.1.1.6 Other components that can be present within a duct tape product are a release coat and a primer coat.

9.1.2 *Electrical tape*

9.1.2.1 Electrical tape, also known as vinyl tape, finds use in applications that require heat resistance / retardance and insulating properties. The two main components are the backing and the PSA.

9.1.2.2 The backing of electrical tape is most commonly made of PVC. Plasticizers, typically phthalate or adipate compounds, are added to this material to impart flexibility to the PVC. Other plasticizers can include alkyl / aryl phosphate compounds and dialkyl tin compounds. Backings vary in thickness and are commonly black in color, due to the addition of carbon black. However, a variety of colored backings are produced and available. In addition to plasticizers, inorganic materials such as lead stearate, lead carbonate, antimony oxide, kaolinite, calcite, and titanium dioxide (anatase or rutile) can also be found.

9.1.2.3 The adhesive can be formulated in several ways, depending on the intended end use, and can be either colorless or black, due to the addition of carbon black. Adhesive formulations typically consist of acrylic-based PSA or highly cross-linked rubber-based PSA. The adhesive layer can also contain plasticizers, either intentionally added by the manufacturer or as a result of migration from the backing layer.

9.1.2.4 Other components that can be present within an electrical tape product are a release coat and a primer coat.

9.1.3 *Packaging tape*

9.1.3.1 Packaging tape is designed as a general-purpose tape used to seal packages. The two main components are the backing and the adhesive.

9.1.3.2 Packaging tape backings are typically clear but also can be found in various shades of tan or brown. Polypropylene in the isotactic form is the most commonly encountered backing. Packaging tape backings can be subdivided into two distinct types based upon their tear resistant properties: MOPP and BOPP. Polyester also can be used for packaging tape backings.

9.1.3.3 Packaging tape adhesives are typically clear but are available in shades of tan or brown. Generally, when the backing is colored, the adhesive is clear and vice versa. While clear adhesives contain no inorganic material, the colored adhesives can contain inorganic material such as iron oxide and titanium dioxide. Adhesive formulations typically are isoprene-based, styrene-isoprene copolymer-based (SIS), or acrylic-based.

9.1.3.4 Other components that can be present within a packaging tape are a release coat and a primer coat.

9.2 *Other tapes*

9.2.1 Other types of tape that can be encountered in forensic casework include, but are not limited to, masking tape (saturated paper tape), filament / strapping tape, cloth tape, and office tape. These tapes would be analyzed in a similar manner as the above-mentioned tapes.

9.2.2 *Masking tape*

9.2.2.1 Masking tape, also known as saturated paper tape, consists of a paper backing with a saturant and an adhesive. This type of tape is used as a masking material for paint applications and other general-purpose applications.

9.2.2.2 The backing of a paper tape is either flatback or creped paper that has been saturated with carboxylated butadiene styrene, acrylonitrile butadiene, or a similar material. The purpose of a saturant is to fill porous material and boost the strength of the backing. The paper alone typically exhibits weak internal and external strengths, and the saturant fills the voids between the paper fibers adding strength to the product and minimizing absorption of paint products.

9.2.2.3 The adhesive for a paper tape is typically an isoprene-based PSA or a styrene-butadiene block copolymer, either of which can contain inorganic filler. Acrylic-based adhesives have been used as well, but for outdoor or "clean release" formulations. Adhesives for saturated tapes are formulated with less tack since strong adhesion to a surface is less desirable in masking applications. As with most tapes, if the product is designed to endure exposure to high heat or chemical reagents, the formulation is cross-linked to provide the needed strength.

9.2.2.4 Other components found within a paper tape can include a backsize layer that is applied to the side of the backing opposite the adhesive. There are a variety of materials that are used for this purpose, such as acrylic and polyvinyl acetate, and the material used depends upon the adhesive formulation. In conjunction with the adhesive formulation, a primer coat can be present.

9.2.3 *Filament / strapping tape*

9.2.3.1 Filament tapes are similar to packaging tapes in construction with the addition of reinforcement material. The backing for this type of tape is typically constructed of oriented polypropylene (low cost) or polyester (high cost). The reinforcement filaments can be glass, nylon fibers, or polyester fibers running in the machine direction. Adhesives found on such tape products can be colored or colorless. The elastomer is typically either isoprene or styrene-isoprene block copolymer.

9.2.4 *Cloth tape*

9.2.4.1 Cloth tapes are most frequently used for medical and athletic purposes. Common cloth backing materials include natural and synthetic woven cloth (e.g., cotton, polyester). Traditionally, adhesives were natural rubber-based, but in recent history have been largely replaced by acrylic copolymers and other synthetic elastomers.

9.2.5 *Office tape*

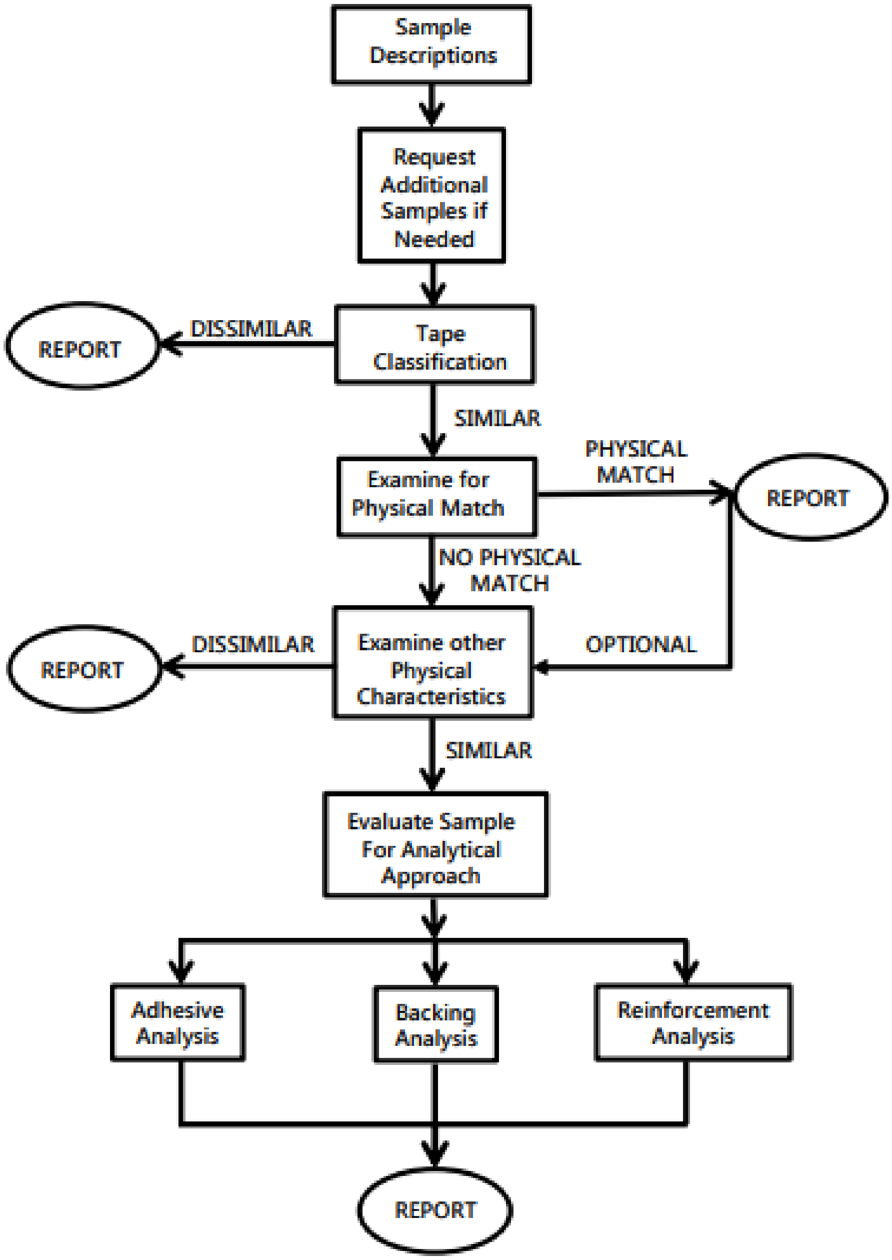
9.2.5.1 Office or stationery tape is comprised of a backing and a PSA. The most common tape backings include cellulose acetate, cellophane, and polypropylene and can range in appearance from clear glossy or matte to a translucent yellow. The PSA is typically isoprene-based, acrylic-based, or styrene-isoprene copolymer-based. As mentioned in the previous tape discussions, a release coat and a primer layer can also be present.

10. Procedure

10.1 A scheme for forensic tape examinations is outlined in Figures 1-4. Potentially useful techniques for the discrimination of tape backings and tape adhesives are listed. For any given comparison, not all the techniques listed in Figure 1 are necessarily required. Tape class, sample size, condition, and layer structure should be considered when determining which techniques to use. The forensic tape examiner should use the most discriminating and least destructive tests prior to those that require more sample preparation or consumption. A review of the general descriptions of the techniques, listed in 10.4 – 10.12, provides guidance for the selection of appropriate methods.

10.2 A minimum analytical scheme (Figure 1) for the comparison of tape includes the following:

Figure 1



10.2.1 Physical characterization of the tape

10.2.2 Separate comparison of each major component (backing, adhesive, reinforcing material) (Figures 2 – 4)

10.2.2.1 The comparison of backings and adhesives shall include the use of at least two instrumental techniques (one for organic and one for inorganic analysis)

Figure 2

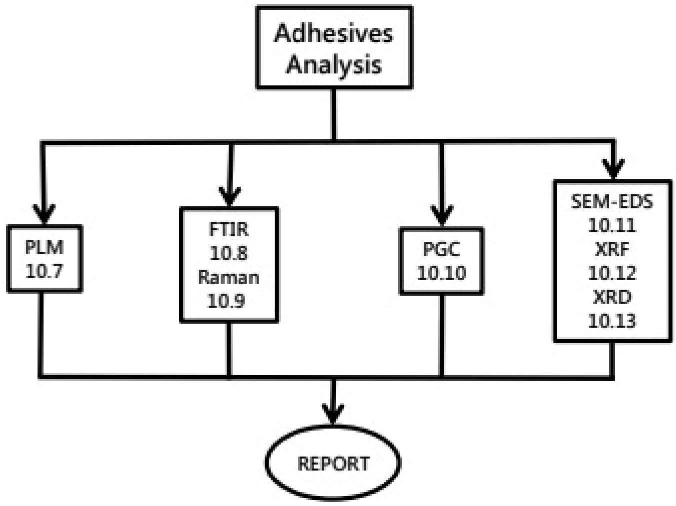


Figure 3

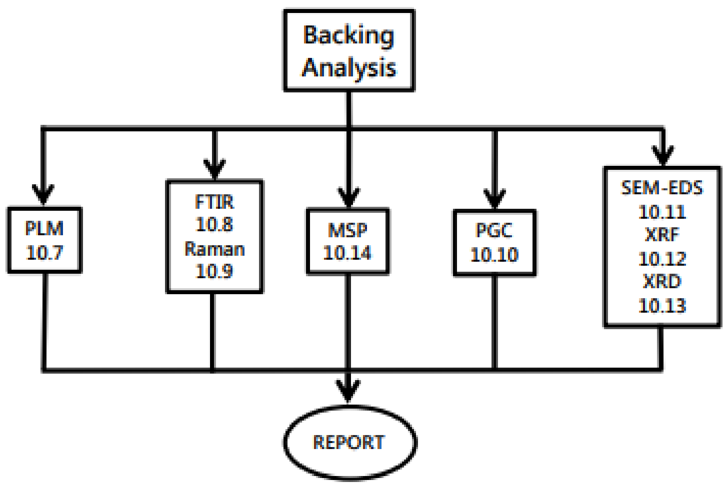
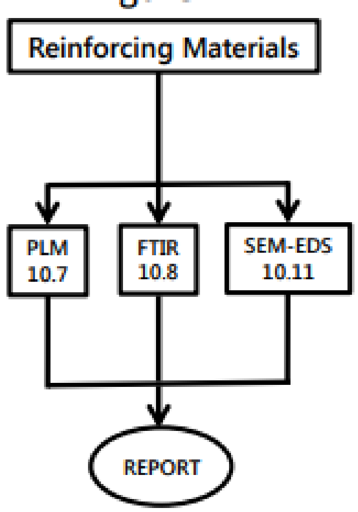


Figure 4



10.3 Characterization of reinforcing materials utilizing appropriate methods (e.g., PLM and FTIR for fabric reinforcement; PLM and elemental analysis for glass). The analysis can be concluded at any point during a comparison if an exclusionary difference is found.

10.4 *Sample description*

10.4.1 The initial evaluation begins with a critical review of each sample's chain of custody, package sealing, and identification markings. In addition, any potential for cross-contamination between samples is evaluated.

10.4.2 The next step in forensic tape analysis is the visual evaluation, description, and documentation of the original condition of the sample(s). This step involves describing the general condition, weathering characteristics, size, shape, color, and classification of the tape. This evaluation can be performed macroscopically both with the naked eye and using a stereomicroscope. If necessary, separate tape from an item or from itself to complete a full examination on the tape.

10.4.3 Written descriptions, sketches, photographs, or other images are used to document each sample's characteristics. The resulting notes shall be sufficient to document the conclusions reached in the examiner's report. Although documentation is discussed at this point in this guide, it is an essential part of all steps in an analysis.

10.5 *Physical Fit*

10.5.1 The most conclusive type of examination that can be performed on tape samples is a physical end match. This involves the comparison of edges, surface striae, and other surface irregularities between samples in which corresponding features possess individualizing characteristics.

10.5.2 Physical fits shall be documented with descriptive notes to include images or videography. Images should contain a scale when possible.

10.5.3 During the course of a physical fit examination, the tape classification is determined, and some of the physical characteristics mentioned below are examined and documented.

10.6 *Physical Characterization*

10.6.1 Macroscopic and stereomicroscopical observations provide initial, and often discriminating, information for tape comparisons.

10.6.2 Color, surface texture, thickness, width, and layer structure can be determined. Cross-sections of the tape sample can be utilized to determine layer structure. If reinforcement, such as scrim or filament fibers, is present in a tape, it should be characterized physically, including scrim count where appropriate.

10.6.3 Strengths of this technique include that it is efficient, highly discriminating, and minimally destructive.

10.6.4 Limitations of this technique include that the physical characteristics of a tape can change as a result of environmental exposure, sample handling, or physical damage.

10.7 *Polarized Light Microscopy*

10.7.1 Characterization of inorganic materials and other tape additives are accomplished with the use of PLM.

10.7.2 Clear and semi-opaque film backings are examined for the optical properties of oriented polymers such as MOPP and BOPP.

10.7.3 The inorganic fillers of the adhesive can be examined under PLM. The morphological and optical features of the different inorganic fillers can be noted.

10.7.4 The cross-section of the backing and adhesive can be observed under PLM.

10.7.5 PLM is also used to evaluate and differentiate the reinforcement fibers of tapes (e.g., duct tape and filament / strapping tape). Refer to ASTM E2228.

10.7.6 Strengths of this technique include that it is an inexpensive and efficient examination. This technique provides discrimination of clear packaging tapes.

10.7.7 Limitations of this technique are that it takes experience to identify the inorganic fillers. Deformation of tapes can affect the PLM observations of MOPP and BOPP.

10.8 *Fourier Transform Infrared Spectroscopy (FTIR)*

10.8.1 FTIR can be used to obtain information about the organic and some inorganic components of the tape. (Refer to ASTM E3085 and E2224). These components include the backing polymer, adhesive elastomer, plasticizers, additives, and reinforcement fibers (Refer to ASTM E3085 and E2224).

10.8.2 The use of a bench ATR (attenuated total reflectance) accessory is useful for surface analysis of the adhesive and backing.

10.8.3 If a multiple layered backing or adhesive is to be subjected to an infrared examination, optimal results are obtained if each layer is analyzed separately.

10.8.4 Strengths of this technique include efficient chemical characterization of primary components of tape with little to no sample preparation time.

10.8.5 Limitations of this technique include the need to separate layers when multiple layers exist in a backing or adhesive. Spectral interpretation of components can be difficult when peak overlap or contamination exists. Any materials co-mingled with the adhesive contribute to the spectrum. If carbon black is present, it can cause loss of absorbance when analyzing tape backings and adhesives.

10.9 *Raman Spectroscopy*

10.9.1 Raman spectroscopy can also be used to obtain compositional information about the backings, adhesives, and additives used in tapes. It provides complementary information to that of FTIR.

10.9.2 A strength of the technique is that it is useful for the analysis of inorganic components and additives. It also can provide some information for organic components.

10.9.3 Limitations of this technique include strong interfering fluorescence produced by some tape components and thermal damage to some materials.

10.10 *Pyrolysis gas chromatography*

10.10.1 Organic constituents of the tape can be further characterized by PGC. This technique uses pyrolytic breakdown products to compare tape structural elements (e.g., adhesive, backing). Individual organic components can then be detected by a flame ionization detector or identified by mass spectrometry.

10.10.2 Strengths of the technique include the ability to identify components when the inorganic fillers in the tape obscure the FTIR interpretation. In addition, it can be more discriminating than FTIR for components such as acrylic polymers and plasticizers.

10.10.3 Limitations of this technique include that it is a destructive technique and can be time consuming. In addition, the examiner needs to ensure that reproducibility is maintained and that there is no sample carryover between runs. The necessity and frequency of replicate and blank runs needs to be established for each system and sample type.

10.11 *Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy*

10.11.1 SEM-EDS can be used to characterize the texture and elemental composition of tape samples. Emitted X-rays provide information regarding the presence of specific elements.

10.11.2 Comparison of the composition of tape backings or tape adhesives is generally performed by a direct spectral comparison or evaluation of relative peak intensities.

10.11.3 Strengths of this technique include the detection of elements present and the texture elucidation (surface topography and distribution of inclusions) of the tape backing.

10.11.4 Limitations of this technique include the depth from which X-rays are produced is dependent upon beam energy, composition and density of the sample, and energy of the X-rays; care needs to be taken to ensure that the EDS data generated are representative of the layer of interest.

10.12 *X-ray Fluorescence Spectrometry*

1.1.1 XRF is another elemental analysis technique that can be used to characterize the elemental composition of tape samples. Like SEM-EDS, emitted X-rays provide information about the presence of specific elements based upon the emission of characteristic X-rays following excitation of the sample by an X-ray source.

10.12.1 Comparison of the composition of tape backings or tape adhesives is generally performed by a direct spectral comparison or evaluation of relative peak intensities.

1.1.2 The detection of elements by XRF is often complementary to that of SEM-EDS.

1.1.3 The strength of this technique is that it is more sensitive to higher atomic weight elements than SEM/EDS.

1.1.4 A limitation of the technique is that it is less sensitive to lower atomic weight elements than SEM/EDS. Depending on the selected excitation energy, the x-ray beam can penetrate through the entire thickness of some tapes yielding bulk analysis results.

10.13 *X-ray Diffraction*

10.13.1 XRD can be used to identify crystalline components of the tape backing and adhesive.

10.13.2 Strengths of the technique include that it is possible to identify crystalline mineral components. There is no interference from non-crystalline organic components and little or no interference between different crystalline mineral components. Polymorphs such as the rutile and anatase forms of titanium dioxide are readily differentiated.

10.13.3 A limitation of this technique is that it cannot identify non-crystalline components.

10.14 *Microspectrophotometry*

10.14.1 Color analysis has a long history in the pigment, paint, dyestuff, and fabric industries and has led to numerous approaches to color measurement and description. The technique can be applied to colored tape backings using either reflectance or transmittance measurements. Although thin cross-sections can be prepared manually, there is often improved reproducibility when using a microtome.

10.14.2 A strength of this technique is that it provides objective color data for colored tape comparisons.

10.14.3 Limitations of the technique include that it can only be applied to colored tape samples. In addition, differences can arise due to weathering or contamination.

10.15 *Laser Ablation Inductively Coupled Mass Spectrometry*

10.15.1 LA-ICPMS is an elemental analysis technique that can complement other organic and inorganic techniques. This technique can be applied to both the tape backings and adhesives.

10.15.2 Strengths of the technique include that it is sensitive and selective, minimizes sample destruction, shortens analysis time, requires little to no sample preparation, and allows for quantitative measurements.

10.15.3 Limitations of the technique include the cost of the instrumentation, lack of matrix-matched reference materials, and required specialized operators.

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