OSAC 2024-S-0016
Standard Guide for Evaluating Physical and Optical Characteristics in Forensic Tape Examination and Comparison

Trace Materials Subcommittee
Chemistry: Trace Evidence Scientific Area Committee (SAC)
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DRAFT OSAC Proposed Standard

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Standard Guide for Evaluating Physical and Optical Characteristics in Forensic Tape Examination and Comparison

1. Scope

1.1. This guide covers techniques and procedures intended for use by forensic science practitioners (FSP) who perform physical examinations and comparisons of pressure-sensitive adhesive (PSA) tapes. Its aim is to provide a description of the techniques used to evaluate the physical and optical characteristics of tape evidence.

1.2. This guide is to be used in conjunction with a broader analytical scheme presented in **Guide E3260**.

1.3. This guide describes various techniques and procedures used in the physical and microscopical examination of PSA tapes including sample handling and preparation; selection, application and evaluation of light microscopical techniques; optical properties of individual components; and evaluation and interpretation.

1.4. The values stated in SI units are to be regarded as standard. Other units of measurement are included in this standard as applicable to industrial usage.

1.5. This standard is intended for use by competent forensic science practitioners with the requisite formal education, discipline-specific training (see **Practice E2917, Practice E3233**), and demonstrated proficiency to perform forensic casework.

1.6. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7. *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. Referenced Documents

2.1. *ASTM Standards*:

D123 *Terminology Relating to Textiles*
C1256 *Practice for Interpreting Glass Fracture Surface Features*
E620 *Practice for Reporting Opinions of Scientific or Technical Experts*
E1732 *Terminology Relating to Forensic Science*
E2225 *Guide for Forensic Examination of Fabrics and Cordage*
E2228 *Guide for Microscopical Examination of Textile Fibers*
E2917 *Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Programs*
E3233 *Practice for Forensic Tape Analysis Training Program*
E3260 *Guide for Forensic Examination and Comparison of Pressure-Sensitive Tapes*
E3392 *Guide for Forensic Physical Fit Examination*

2.2. *Other Documents*

OSAC 2023-N-0027 *Standard Guide for Forensic Trace Evidence Recovery*

ISO/IEC 17025 *Testing and Calibration Laboratories*

3. Terminology

3.1. *Definitions:* For terms used in this document, refer to **Standard E1732, Guide E3260,** and **Standard D123**.

4. Summary of Guideline

4.1. This guide covers macroscopical examinations (including comparisons and characterizations for investigative leads) of the physical and optical properties of the backing, adhesive and reinforcing materials of tape. Structural details such as design, construction, and composition, can provide information that assists the FSP in determining possible classification or manufacturer (for investigative leads). The intent of a tape comparison the physical and optical characteristics, instrumental analyses are warranted (refer to **Guide E3260**).

4.2. This guide describes the features which are observed and documented in the various layers of pressure-sensitive tape. However, not all of the described characteristics are present in all types of tapes.

5. Significance and Use

5.1. Physical characterization is the initial step in a comprehensive forensic pressure-sensitive tape examination. The construction, composition, and color of tapes vary and, therefore, are useful characteristics to evaluate. Macroscopical characteristics and physical measurements are efficient, highly discriminating, and minimally destructive.

5.2. This guide lists the various aspects of the physical and optical characterization of pressure-sensitive tapes but does not prescribe a specific order in which they should be completed.

5.3. Optical characterization of tape films, adhesives, and reinforcing materials is performed using transmitted and polarized light. Some tapes exhibit variability in optical characteristics that is not readily detected using other instrumental or physical examinations.

5.4. If tape samples are damaged or altered (e.g., environmental exposure, chemical exposure, stretching), the changes can limit the information obtained from the analyses. If the tape does not allow for the full range of examinations, the reasons for the limited examinations are documented.

5.5. Inter-roll and intra-roll variability can be observed in some measured physical features (e.g., tape width, scrim count). When possible, variances are best derived from a known roll submitted with the case. Alternatively, similar products can be evaluated to gain insight into expected variances. Approximate industry tolerances for these features in duct tape have been reported in the literature (**1**).

5.6. The evaluation of physical and optical characteristics can be concluded at any point during a comparison if an exclusionary difference is found.

6. Equipment

6.1. General list of common materials utilized:

6.1.1. Camera
6.1.2. Illumination techniques (e.g., light box, UV lighting, oblique lighting, fluorescence)
6.1.3. Liquid nitrogen
6.1.4. Magnifier
6.1.5. Measuring devices (e.g., ruler, micrometer, caliper)
6.1.6. Microscopes (e.g., stereomicroscope, polarizing microscope, comparison microscope)
6.1.7. Mounting media of various refractive indices (e.g., Permount, Entellan)
6.1.8. Packaging and documentation materials (e.g., labels, markers)
6.1.9. Polarizing filters
6.1.10. Sample handling tools (e.g., probe, forceps)
6.1.11. Sample preparation materials (e.g., microscope slides, coverslips)
6.1.12. Solvents
6.1.13. Source of gentle heat (e.g., lamp, hair dryer)

7. Sample Handling

7.1. Tape evidence can be a source for other trace evidence (e.g., hairs, fibers, paint, glass, and explosives), latent print evidence, and DNA evidence. The order in which the examinations are conducted is resolved on a case-by-case basis.

7.2. The condition of items as received is documented prior to conducting any examinations.

7.3. Transient evidence (e.g., hair, fiber, paint) is documented, collected, and preserved prior to conducting any tape examinations.

7.4. It is recommended that an unaltered representative sample of tape be collected prior to the start of any chemical processing.

7.4.1. The location of any removed sample is documented.

7.4.2. Tape ends are left intact to preserve them for physical fit examinations.

7.4.3. Samples are selected from areas of the tape that are least affected by external influence (e.g., dirt, blood, weathering, latent print processing techniques).

7.5. External contaminants (e.g., fingerprint powders, chemicals) are removed from film backings as needed using a solvent (e.g., alcohol, water) during examination.

7.6. Tape received in a tangled condition or on a substrate can be separated manually.

7.6.1. Techniques such as gentle heat, liquid nitrogen freezing, or solvents can be used to aid in manual separation. Solvent use can affect the outcome of subsequent analyses and is, therefore, applied only as necessary.

7.6.2. Forceful manual manipulation of tape can cause distortion in physical characteristics.

7.6.3. Tapes should not be placed onto paper, cardboard, or surfaces that could affect future testing. Certain substrates (e.g., acetate, resealable plastic bag) removal or chemical testing after long-term storage (**2**).

8. Initial Observations

8.1. A preliminary examination of tape construction includes its general condition (e.g., wadded, flat piece, fragments) and appearance, both with the unaided eye and using a stereomicroscope. These features can include, but are not limited to:

- 8.1.1. Color
- 8.1.2. Type of tape (e.g., duct, electrical, packaging)
- 8.1.3. Number of pieces
- 8.1.4. Presence and extent of weathering
- 8.1.5. Physical damage
- 8.1.6. Indications of prior testing (e.g., latent powder, latent print chemicals)
- 8.1.7. Condition of the ends (e.g., cut, torn)
- 8.1.8. Tape edge characteristics (e.g., crush-cut)
- 8.1.9. Presence of any adhering material
- 8.1.10. Tape roll core markings and packaging information (if available)

8.2. The ends of the tape are evaluated for suitability for physical fit examination, refer to **Guide E3392.**

9. Sample Preparation

9.1. This section describes techniques used to prepare the different components of tape for examination. The backing, adhesive, and reinforcement layers of tapes are examined individually or as a cohesive unit. Not all of the following sample preparation techniques are necessarily utilized for every type of tape. Not all property evaluations require isolation of individual tape components. Samples being compared are prepared and analyzed in the same manner.

9.2. The analysis of these preparations is covered in Sections 10 through 13 below.

9.3. Preparation for thickness determination

9.3.1. Full thickness preparation

9.3.1.1. Full tape thickness can be determined by viewing full-thickness cross sections with a microscope and using a calibrated ocular scale to measure the thickness (see 9.4 on cross-sections).

9.3.1.2. Alternatively, place the tape, adhesive side down, on a smooth, rigid, regular substrate (e.g., glass slide, cover slip) and place a second piece of substrate on top of the backing. Using a caliper or micrometer, measure the thickness of the tape and pieces of substrate all together, then subtract the thickness of the pieces of substrate.

9.3.1.3. Multiple measurements are recommended to determine variance.

9.3.2. Backing thickness preparation

9.3.2.1. The sample is prepared as noted in 9.3.1 except any adhesive and reinforcing material is removed. This isolates the backing material for measurement.

9.4. Preparation of tape cross-sections

9.4.1. Cross-sections of tapes can be made of the full thickness of the tape or of the backing alone.

9.4.1.1. If cross-sectioning only the backing, an appropriate solvent (e.g., hexane, xylene) is used to remove the adhesive and any reinforming materials.

9.4.1.2. Full thickness tape can be cross-sectioned without preparation.

9.4.2. The application of liquid nitrogen to the tape sample or embedding the tape sample in a suitable medium (e.g. Norland Optical, epoxy resin) can facilitate cross-sectioning.

9.4.3. The tape is cut using a technique that provides thin cross-sections (e.g., hand-sectioning, microtoming).

9.4.4. The cross-section(s) are mounted on microscope slides in an appropriate mounting medium with a coverslip.

9.5. Preparation of tape backings for PLM examination

9.5.1. Tapes with translucent or transparent backings are appropriate for examination using PLM.

9.5.2. Some translucent and transparent tapes require the adhesive to be removed using a suitable solvent (e.g., hexane, xylene) in order to properly examine the backing using PLM.

9.5.2.1. Clear Packing/Office Tape: There is no need to separate the adhesive from the film for the microscopic examination of these types of tape.

9.5.2.2. Brown Packing Tape [clear backing, colored adhesive]: The colored adhesive is removed in order to perform a microscopical examination of the backing.

9.5.3. After removing the adhesive (if necessary), an area of tape that has both machine edges intact and appears to be in its original state (i.e., has not been damaged by heat, stretching, or contamination) is selected and sampled. This piece is placed directly onto a clean microscope slide, adhesive side down. An arrow noted on the slide above the sample can help keep track of which direction is the machine direction.

9.6. Preparation of tape adhesives for microscopical examination

9.6.1. A small sample of adhesive is separated from the backing by, for example, pinching with tweezers or gently scraping with a probe, taking care to avoid including fibers or debris in the sample.

9.6.2. The sample is placed onto a microscope slide.

9.6.3. A solvent, such as xylene, can be added to the adhesive sample on the slide. This will disperse the adhesive’s rubber base and make the sample easier to view. The sample is allowed to dry prior to proceeding.

9.6.4. A suitable mounting medium and a coverslip are applied. Note: Most minerals found in adhesives can be evaluated in two preparations using mounting media having refractive indices of 1.66 and 1.55.

9.7. Preparation of reinforcing materials for microscopical examinations

9.7.1. Fibers from the reinforcing materials are gently pulled and cut from the adhesive for mounting, if not previously separated.

9.7.2. The fibers are then rinsed of any adhering adhesive using hexane or other suitable solvent.

9.7.3. Since the warp and fill yarns can be cotton/polyester blends, the entire yarn is loosely mounted on a microscope slide in a mounting medium. Warp and fill yarn fibers are mounted separately. For additional information regarding the mounting of fibers for microscopy, refer to **Guide E2228**.

10. Overall Measurements

10.1. Full tape width is evaluated and documented.

10.1.1. This measurement is only needed if the full width of the tape is present.

10.1.2. Width measurements are documented to the nearest 0.5 mm. The measured width can vary from the nominal width of the tape. Nominal width is defined as the manufacturer-intended width of the tape. (**3**, **4**)

10.2. Full tape thickness (backing and adhesive) can be evaluated. Note: Use caution when evaluating the significance of a comparison of thickness, as thickness can also be affected by other factors (e.g., intra-sample variability, stretching).

10.3. Multiple measurements are recommended to determine variance.

11. Backing Analysis

11.1. General information

11.1.1. The physical attributes of the backing at both a macroscopical and microscopical level are characterized using multiple illumination sources.

11.1.2. Transparent and translucent film backings are examined for optical properties and additives as described below. The techniques described in this section are recommended for clear packing tapes; however, they are applicable to other non-reinforced tapes with transparent or translucent backings.

11.2. The type of backing is determined and documented (e.g., paper, polymer film).

11.3. Layer structure

11.3.1. Using a compound light microscope to view the cross-section, the number of backing layers is determined. For example, duct tape backings often have multiple layers.

11.4. Thickness

11.4.1. The overall thickness of the backing and individual layers is determined.

11.4.2. In packing tapes with clear backings, the relative total backing thickness can also be compared using the optical properties. See Section 11.11 below.

11.5. Color: The backing is examined macroscopically and under a stereomicroscope for general color and appearance.

11.6. Gloss: Whether the tape surface is glossy or matte is noted.

11.7. Texture: Using a stereomicroscope, the top of the backing is examined for manufacturing artifacts such as calendaring marks, striations, dimples, and inclusions. The shapes and type of markings are documented.

11.8. Fluorescence: The backing can be examined using alternate light sources.

11.9. Optical properties: polypropylene film orientation

11.9.1. Microscopical determination

11.9.1.1. Using a polarized light microscope with transmitted light, a sample of clear backing film that has been mounted on a microscope slide is examined.

11.9.1.2. The top surface of the backing is brought into focus.

11.9.1.3. The polars are crossed and the stage is rotated until the sample goes to extinction.

11.9.1.4. The stage is rotated to just off of extinction, and the patterns in the film are observed. These patterns can be sharpened by refocusing and closing down the aperture diaphragm.

- A bi-directional pattern is seen in biaxially-oriented polypropylene (BOPP) backings and is exhibited as an “X” pattern.
- A unidirectional pattern is seen in monoaxially-oriented polypropylene (MOPP) backings and can be hazy and show more than one interference color that streaks in a singular direction.

11.9.1.5. The angles of the crosshatches in the BOPP tape as described above can vary from one tape backing to another, but will be consistent throughout a roll of tape. These angles can be determined with an appropriate eyepiece reticle or other appropriate method.

11.9.2. Macroscopical determination

11.9.2.1. A sample of clear backing film is placed between two sheets of polarizing film.

11.9.2.2. The polarizing film sheets and backing are placed onto a lightbox (or other source of even backlight illumination).

11.9.2.3. One sheet of polarizing film and the backing are kept stationary and the second sheet of polarizing film is rotated until the backing sample goes to extinction.

- BOPP backings exhibit one point of extinction (at 180 degree of rotation). A bi-directional pattern is seen in BOPP backings and is exhibited as an “X” pattern.
- MOPP backings exhibit two points of extinction (at 90 degrees of rotation). A unidirectional pattern is seen in MOPP backings and can be hazy and show more than one interference color that streaks in a singular direction.

11.10. Optical properties: determination of the extinction angle relative to the machine direction

11.10.1. The machine direction of the tape (parallel to the length of the tape) relative to the extinction direction can vary from 0 to 35 degrees between different tapes (**5**).

11.10.2. Procedure

11.10.2.1. Using plane-polarized light and a polarized light microscope, the surface of the tape is brought into focus.

11.10.2.2. One of the machine edges of the tape is aligned with the vertical line of the eyepiece reticle. The stage position in degrees is noted.

11.10.2.3. The polars are crossed and the stage rotated until the tape film is at its nearest full extinction. Again, the stage position is noted.

11.10.2.4. The difference in degrees is the extinction angle relative to the machine edge.

11.11. Optical properties: observation and interference colors

11.11.1. Slight differences in thickness of the polymer film backing of clear packing tapes will show noticeably different interference colors. These interference colors depend only on the tape backing thickness, not the overall tape thickness (backing + adhesive). The clear adhesive layer is isotropic and does not contribute to the interference colors.

11.11.2. Procedure – Microscopical Determination

11.11.2.1. Using a polarized light microscope, the surface of the tape is brought into focus.

11.11.2.2. The polars are crossed and the stage is rotated to the position of maximum brightness. The interference color is noted.

11.11.2.3. If a comparison between two tapes is performed, it is recommended that the two tapes be mounted side-by-side on a single microscope slide with machine edges in close proximity. This allows the samples to be viewed on the polarized light microscope simultaneously in the same field of view under the same conditions. Alternatively, a comparison microscope can be used.

11.11.3. Procedure – Macroscopical Determination

11.11.3.1. Using a light box, orient two polarizing filters at 90 degrees to each other.

11.11.3.2. Place a piece of tape between the polarizing filters. Orient the tape 45 degrees off the axis of the polarizing filters.

11.11.3.3. Note the interference colors.

11.11.4. Irregularities in the thickness of the tape film can be observed under crossed polars as multiple interference colors in any given field.

11.11.5. Some tape films do not exhibit complete extinction as they are rotated, or they can show undulose extinction (i.e., areas of brightness and darkness).

11.12. Inclusions

11.12.1. Using a polarized light microscope with plane-polarized light and under crossed polars, examine the mounted tape backings for the presence of any inclusions.

11.12.2. In duct tapes, the gray color of polyethylene film backing is due to the presence of aluminum powder. The density, size and dispersion of the aluminum particles can be seen by viewing the cross section of the backing.

11.12.3. Some clear tape films contain additives that are visible in transmitted or polarized light and their presence is useful for comparison purposes between tapes. Their optical properties (e.g., size, distribution, relative interference colors) are assessed and documented.

12. Adhesive Analysis

12.1. The physical attributes of the adhesive present are characterized at both a macroscopical and microscopical level.

12.2. The macroscopical and microscopical examination of adhesives includes the following:

12.2.1. Color: The adhesive is examined macroscopically and under a stereomicroscope for general color and appearance.

12.2.2. Gloss: Observations regarding the level of gloss of the adhesive are documented.

12.2.3. Tack: Observations regarding the tack or stickiness of the adhesive can be considered.

12.2.4. Fluorescence: The adhesive is examined under alternate light sources as some adhesives fluoresce and others do not.

12.2.5. Inclusions: Any inclusions or other material within the adhesive are documented.

12.3. Microscopical examination of the adhesive can be performed; it is most useful for opaque adhesives.

12.3.1. The inorganic fillers within adhesives can be examined under transmitted plane- and crossed-polarized light.

12.3.1.1. See Section 9.6. for sample preparation.

12.3.1.2. Observations regarding the different inorganic filler particles that are observed, including a basic description of their morphological features, optical properties, or both are documented. Frequently encountered inorganic fillers include, but are not limited to, kaolinite, calcite, dolomite, titanium dioxide, zincite, or talc.

13. Reinforcing Materials Analysis

13.1. Full fabric and fiber examinations are outside the scope of this document. Refer to the appropriate standards (e.g., **Guide E2225**, **Guide E2228**) for additional guidance on the minimum requirements for identification of various fabric and fiber types.

13.2. Reinforcement materials are characterized at both a macroscopical and microscopical level.

13.3. Construction

13.3.1. Duct tape: The primary weave patterns found in duct tapes are weft-insertion and plain weave.

13.3.1.1. Weft- insertion has chain-stitch warp yarns with texturized filaments in the fill direction.

13.3.1.2. A plain weave has a one-over/one-under pattern.

13.3.2. Filament tape: The fibers in filament tape are only in the warp direction and most often consist of plastic or glass filaments.

13.4. Fluorescence

13.4.1. The fluorescence of a section of the scrim is examined using short-wave ultraviolet illumination, long-wavelength ultraviolet illumination, or both.

13.5. Scrim count

13.5.1. The number of warp and fill yarns per unit of measure (e.g., centimeter, inch, full tape width) is documented (**6**).

13.5.2. Multiple measurements are recommended to determine variance.

14. Results and Interpretations

14.1. Comparison of physical and optical properties is the first step in the tape comparison process in which characteristics such as the color, width, construction, and fluorescence are considered in the evaluation as to whether exclusionary differences exist between compared samples.

14.2. Results and interpretations for comparisons of physical and optical properties between tapes are based upon the observation of all differences, or lack thereof, between sample sets prepared in similar fashions.

14.3. When evaluating differences between tapes, consider sample limitations (e.g., small, damaged, or dirty samples) and manufacturing variability.

14.4. When exclusionary differences are observed between compared physical and optical properties in tape, the sources of the samples are considered distinguishable. Exclusionary differences in the comparison of physical and optical properties of tape: 1) are outside the variability of the physical and optical properties (e.g., color, width, construction, fluorescence) of tapes originating from the same source; and 2) cannot be explained by considerations such as sample heterogeneity, contamination, different sample conditions, or different sample histories.

14.5. When no exclusionary differences are observed between compared physical and optical properties, the sources of the samples are considered indistinguishable by physical and optical comparison. Differences that are not considered exclusionary: 1) are within the variability of tapes originating from the same source; or 2) can be explained by considerations such as sample heterogeneity, contamination, different sample conditions, or different sample histories. If no exclusionary differences are observed in this comparison, samples can be analyzed by other analytical techniques to provide additional information about the potential relationship between the sources of the samples.

14.6. Physical and optical property comparison is one part of a multi-analytical comparative approach. Physical and optical property comparison data alone can be used to distinguish the sources of compared samples, but they are not used independent of data obtained from other analytical techniques to reach an overall opinion regarding the potential relationship between the sources of the samples. An overall opinion that sources are indistinguishable is only reported when no exclusionary differences are observed in any analytical techniques that were applied in accordance with Guide **E3260**.

15. Documentation

15.1. Case notes include the particular characteristics used in the physical and microscopical comparisons, including measured values, descriptions, diagrams, or photomicrographs.

15.2. A description of the evidence analyzed, sample preparations, and equipment used are included in the case notes, case record, or otherwise documented in accordance with FSSP procedures.

15.3. The examination documentation shall contain sufficient detail to support the interpretations and opinions such that another qualified FSP could independently evaluate the documentation and form an independent opinion. FSPs shall follow all accreditation guidelines (e.g., ISO/IEC 17025) as well as the FSSP's standard operating procedures and quality assurance guidelines (refer to Practices E1492 and E620 and ISO/IEC 17025).

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