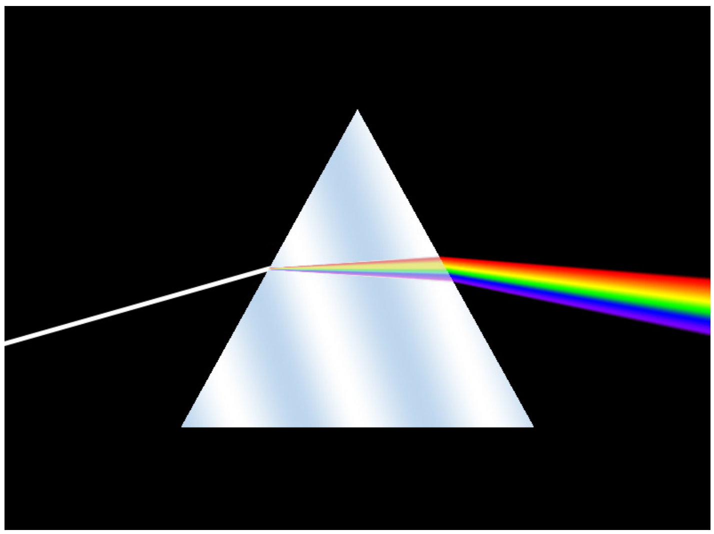
Washington State Patrol



Crime Laboratory Division

Materials Analysis
Secondary Foundation Training Manual

December 2015

Contents

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This manual contains an outline for training and/or assessing a forensic scientist in the area of materials analysis. Each scientist will have a unique training program depending on the individual's strengths and weaknesses, previous background, the needs of the laboratory, and available personnel and equipment to provide the training. The sequence in which the various sections are presented should not necessarily be considered as a mandatory order of training.

This manual endeavors to promote and maintain consistency and quality among forensic scientists performing materials analyses across the Crime Laboratory Division. Certain inherent aspects of chemical analysis prohibit the establishment of a rigid set of standard procedures to cover every case. Sufficient latitude should be given to allow for independent thought and individual freedom in selecting alternative courses of action. Upon completion of this training program, the trainee will be thoroughly familiar with the options available to perform an examination of most types of evidence that may be received.

1.2 ORGANIZATION OF THE TRAINING MANUAL

The training manual consists of several study segments, each covering different aspects of chemical analysis.

Each study segment is comprised of six parts:

- The *Objectives* summarize the purpose of each training segment.
- The *Topic Areas* designates topics to be included in the training segment.
- The *Safety* section indicates specific safety information relating to the training segment.
- The *Suggested Readings* section lists the reference material that should be read to successfully complete the study segments. The reading assignments are cumulative; comprehension of prior readings may be required to successfully complete study/discussion questions and exercises of subsequent study segments. It may not be necessary or practical to read every reference listed. The trainee will work with the trainer for specifics.
- The *Study Questions* have a number of purposes:
    - To assist reading comprehension by providing a focus on certain concepts prior to completing the Reading section;
    - To evaluate understanding of relevant concepts after completing the Readings; and
    - To promote active discussions between the trainer, trainee and trainee's co-workers using the questions as a starting point.
    - Written answers to these questions will be maintained in the training notebook as documentation of training.
- The *Practical Exercises* are designed to provide the trainee first-hand experience with the main concepts of each study segment. Data or written explanation for each Practical Exercise must be maintained in the training notebooks.

Module 1 covers Advanced Microscopy, Special Applications in Microscopy and Microchemical Methods.

Module 2 covers Microspectrophotometry.

Module 3 of the Secondary Foundation includes:

- Evidence Screening and Evaluation of Trace Evidence
- Introduction to Bloodstain Pattern Recognition
- Damage Assessment

- Physical Match

A written examination will be given after each module. Competency testing will follow Module 3. Co-signed casework for Module 3 may begin with successful completion of the written and competency testing. An IOC will be written by the trainer upon the successful completion of co-signed casework recommending the trainee for independent casework. Once the IOC has been approved through the chain of command, the trainee will be allowed to perform independent casework for Physical Match, Damage Assessment and Evidence Screening & Trace Evidence Recovery. For trainees who will not be trained in all Secondary Foundation Training Modules, a modified training plan will be approved prior to the commencement of training.

The instructor is responsible for ensuring that the trainee is prepared to testify as an expert witness. This can be done with mock trials, prearranged as well as impromptu question and answer sessions, and observation of courtroom testimony given by experienced forensic scientists. One or more mock trials will be scheduled during the training program.

2 ADVANCED MICROSCOPY

2.1 OBJECTIVES

- To expand the trainee's knowledge of microscopy principles and theory.
- To gain practical experience in identifying and classifying materials using PLM methods.
- To prepare the trainee for more advance study of chemical microscopy techniques.
- To incorporate PLM into a holistic analytical approach in Materials Analysis.

2.2 TOPIC AREAS

1. Review of terms and definitions
    a. Refractive index
    b. Birefringence
    c. Retardation
    d. Optic Sign
    e. Pleochroism
    f. Dispersion
    g. Snell's Law
    h. Abbe's Law (Resolving Power)
    i. Angular and Numerical Aperture
2. Review of crystal systems
    a. Crystal forms
    b. Crystal habits
    c. Miller Indices
3. Behavior of light in crystals and the indicatrix
    a. Isotropic crystals
    b. Uniaxial crystals
    c. Biaxial crystals
4. Measurement of refractive indices
    a. Isotropic crystals
    b. Uniaxial crystals
    c. Biaxial crystals
5. Conoscopic observations and measurement
    a. Determination of optic sign
    b. Measurement of the Optic Axial Angle (2V)

2.3 SAFETY

Tools for the manipulation of small particles are sharp and pose cutting and puncture-wound hazards. Care must be exercised in the use of fine tweezers, scalpels, tungsten needles, and other sharp tools. Refractive index immersion liquids may pose health hazards if there is skin/eye contact or ingestion.

2.4 SUGGESTED READINGS

1. Bloss FD. 1990. An Introduction to the Methods of Optical Crystallography. Marietta (OH):R.A.N. Publishers.
2. Bloss FD. 2000. Crystallography and Crystal Chemistry Chapters 1, 2, 5, & 8. Washington (DC): Mineralogical Society of America.
3. Chamot EM, Mason CW. 1944. Handbook of Chemical Microscopy. Vol. 1. Chapters 9, 10 & 11. New York (NY):John Wiley & Sons.
4. Kerr PF. 1959. Optical Mineralogy. New York (NY): McGraw-Hill Book Company.

5. MCrone WC, Draftz RG, Delly JG. 1967. The Particle Atlas. Ann Arbor (MI): Ann Arbor Science Publishers.
6. McCrone WC, McCrone LB, Delly JG. 1984. Polarized Light Microscopy. Chicago (IL):McCrone Research Institute.
7. Stoiber RE, Morse SA. 1994. Crystal Identification with the Polarizing Microscope. New York (NY): Chapman and Hall.
8. Wood EA. 1977. Crystals and Light: An Introduction to Optical Crystallography. 2nd Ed. New York (NY): Dover Publications.
9. Winchell, A.N., Winchell, H. 1989. The Microscopical Characters of Artificial Inorganic Solids Substances: Optical Properties of Artificial Minerals. Chicago (IL):McCrone Research Institute.

2.5 STUDY QUESTIONS

1. Define *retardation* in terms of the behavior of polarized light in an anisotropic crystal.
2. Define *optic sign* in a uniaxial crystal and in a biaxial crystal. What is the difference between *optic sign* and *sign of elongation*?
3. What is the *acute bisectrix* in a biaxial positive crystal?
4. Define *optic axial angle*.
5. Explain how to measure the principle refractive indices of a uniaxial crystal.
6. Explain how to determine optic sign of uniaxial and biaxial crystals using conoscopic observations.
7. Explain microscope set-up for conoscopic observations.
8. Define the crystal systems.
9. Describe common crystal forms observed in the different crystal classes.
10. What is the maximum theoretical resolution possible with a 40X/0.65 NA objective?
11. Define *dispersion* as it relates to refractive index of a material.

2.6 PRACTICAL EXERCISES

1. Determine the refractive index of five known isotropic crystals.
2. Determine principle refractive indices of five known uniaxial crystals.
3. Determine the optic sign of five known uniaxial crystals using conoscopy.
4. Measure the minimum and maximum refractive indices of five known biaxial crystals.
5. Estimate 2V and determine the optic sign of five known biaxial crystals using conoscopy.
6. Measure optical properties (refractive indices, anisotropy, etc) of at least five unknown materials. Using tables from Winchell, develop a list of possible compound identities of each.

3 SPECIAL APPLICATIONS IN MICROSCOPY

3.1 OBJECTIVES

- To obtain an understanding of image contrast methods, dispersion staining, fluorescence microscopy, hot stage and fusion microscopy using equipment that is currently available in the crime laboratory division.

3.2 TOPIC AREAS

1) Phase contrast
2) Darkfield (darkground) illumination
3) Oblique illumination
4) Dispersion staining
5) Fluorescence microscopy
6) Hot state microscopy

3.3 SAFETY

Tools for the manipulation of small particles are sharp and pose cutting and puncture-wound hazards. Care must be exercised in the use of fine tweezers, scalpels, tungsten needles, and other sharp tools. Refractive index immersion liquids may pose health hazards if there is skin/eye contact or ingestion. Do not open the housing or handle a mercury-vapor lamp housing while it is illuminated or hot; in addition to the possibility of burns there is always the danger of explosion.

3.4 SUGGSETED READINGS

1) Abramowitz M. 1985. Microscope Basics and Beyond. Vol. 1. Lake Success (NY): The Olympus Corporation.
2) Abramowitz M. 1987. Contrast Methods in Microscopy-Transmitted Light. Vol. 2. Lake Success (NY): The Olympus Corporation.
3) Abramowitz M. 1990. Reflected Light Microscopy-An Overview. Vol. 3. Lake Success (NY): The Olympus Corporation.
4) Abramowitz M. 1993. Fluorescence Microscopy-The Essentials. Vol. 4. Lake Success (NY): The Olympus Corporation.
5) Bradbury S, Evennet P. 1996. Contrast Techniques in Light Microscopy. Bios Scientific Publishers.
6) Delly JG. Essentials of Polarized Light Microscopy. Most current edition available. Various chapters as recommended by the trainer.
7) McCrone WC, McCrone LB, Delly JG. 1984. Polarized Light Microscopy. Chicago(IL): McCrone Research Institute.
8) McCrone W, Kilbourn JH. 1985. Fusion Methods: Identification of Inorganic Explosive. The Microscope.33(2):73-90.
9) Robertson J, Grieve M. 2003. Forensic Examination of Fibres. 2nd Ed. Philadelphia (PA): Taylor & Francis. p. 171-172.
10) Wood EA. 1977. Crystals and Light: An Introduction to Optical Crystallography. 2nd Ed. New York (NY): Dover Publications.
11) PowerPoint Presentation: Using a Hot-Stage to Determine the Melting Point of Inorganic Explosives. This presentation can be found on the Portal in Materials Analysis Training & Reference Material.

3.5 STUDY QUESTIONS

1) Phase Contrast
   a) Sketch a ray path diagram for a phase contrast microscope.
   b) List at least ten different types of specimens where phase contrast would be useful or necessary to observe morphology.
   c) How can phase differences arising from colorless transparent specimens be converted to brightness differences?
   d) What is the difference between a phase ring (phase plate) and a phase annulus?
   e) What symbols would be inscribed on a phase objective to distinguish it from other objectives?
2) Darkfield Illumination
   a) When would darkfield illumination be used?
   b) With no specimen present on a slide, what would you see using transmitted darkfield illumination?
   c) Why do microscope slides need to be cleaned especially well when using darkfield illumination?
   d) Can this method be used in epi-illumination?
   e) Sketch a ray path diagram for transmitted darkfield illumination.
3) Oblique Illumination
   a) How would you obtain oblique illumination using the PLM in transmitted brightfield mode?
   b) How does oblique illumination work? Sketch a ray path diagram for oblique illumination.
4) Dispersion Staining
   a) What is dispersion?
   b) What is the difference between central stop and annular stop dispersion staining?
   c) What is a ‘stop’ and where is it positioned?
   d) Describe how you would set-up a microscope for dispersion staining.
   e) Can you use dispersion staining successfully on isotropic colored specimens such as garnet?
   f) What information can be gathered from using dispersion staining?
5) Fluorescence Microscopy
   a) Describe the difference between photoluminescence and fluorescence.
   b) What is an excitation filter?
   c) Why are glass microscope slides often not used in fluorescence microscopy?
   d) What is a dichromatic mirror?
   e) Why are mercury and xenon arc lamps used in fluorescence microscopy?
   f) What types of trace evidence materials may fluoresce and why?
6) Hot Stage Microscopy
   a) What are the practical uses for hot stage microscopy?
   b) What is fusion microscopy?
   c) What are the problems associated with using a hot stage to determine a precise melting point?

3.6 PRACTICAL EXERCISES

1) Phase Contrast
   a) Disassemble and then re-assemble and center a phase contrast system on a polarized light microscope noting all the components and their proper names. Have your trainer check your set-up.
   b) Examine the following unstained specimens mounted on slides using both transmitted polarized light and phase contrast methods. Record and contrast the differences seen between PLM and PC. Photograph these specimens:
      i) Semen
      ii) Buccal cells
      iii) Head hair

iv) Glass particles having the same RI as mounting media
v) Hornblende
vi) Diatoms

c) Can you think of any further examples where phase contrast methods would be useful?

2) Darkfield Illumination
   a) Make a darkfield stop from black paper and center it on top of the substage condenser. Show your trainer how it works.
   b) Set-up your microscope for transmitted darkfield illumination and examine the following specimens. Record and contrast the differences between PLM and DF. Photograph these specimens:
      i) Semen
      ii) Buccal cells
      iii) Head hair
      iv) Glass particles having the same RI as mounting media
      v) Hornblende
      vi) Diatoms
3) Oblique Illumination
   a) Set-up an epi-oblique illumination system on your PLM using a separated bifurcated fiber optic light. Have your trainer check your set up.
   b) Examine an assortment of different specimens such as a penny, dust, polished rock or concrete directly placed on a slide. Mount the following in water with a coverslip and examine. Practice moving the fiber optic light at a variety of angles while viewing these specimens:
      i) Aluminum flakes from flash powder
      ii) Hair
      iii) Skin cells
4) Dispersion Staining
   a) Set-up a microscope for central stop dispersion staining and have your trainer check it.
   b) Mount a few grains of sodium chloride (RI nD=1.544) and strontium nitrate (RI nD = 1.5878) in Cargille liquid that is very close to their respective RIs. Observe and record your observations. Next mount the sodium chloride and strontium nitrate in liquids that are slightly higher than their RIs and then others that are slightly lower and record your observations. What colors do you see when the liquid is higher? Lower?
   c) Nylon has a parallel RI in the neighborhood of 1.560 and perpendicular RI in the neighborhood of 1.520. Mount one fiber in Cargille 1.524 and one in 1.564. Record the colors you see.
   d) Sodium sulfite is hexagonal, uniaxial negative, $\varepsilon = 1.515$ and $\omega = 1.565$ (Winchell's page 120). Take the sample of sodium sulfite provided by your trainer and examine it. Place some crystals in High Dispersion Cargille liquid 1.515. Look for particles that show some purple/orange/red-magentas in all orientations when you rotate the stage. When you find one of these particles move to the 40X objective, put in your Bertrand lens and see if you can see the interference figure. Can you determine the sign of the crystal?
   e) Obtain an unknown mixture (two particle types) from your trainer and mount in a High Dispersion Cargille liquid. Screen the sample and estimate the volume percent of each component.
5) Fluorescence Microscopy
   a) Set-up one or more microscopes for reflected fluorescence microscopy (DMR, DMR with microspectrophotometer, etc.). Have your trainer check the set-up.
   b) Observe fluorescence intensity and color using a variety of known materials supplied by your trainer. Record your observations. If your microscope is so equipped, change excitation and barrier filters or filter cubes to different wavelengths and record fluorescence at various wavelengths.
   c) Mount the following particles (if available) supplied by your instructor exhibiting fluorescence on individual microscope slides in a variety of mounting media. Using a variety of excitation

wavelengths, compare the background auto-fluorescence of each mounting media and record observations. Which mounting media showed the least auto-fluorescence?

i) Glycerin/methanol
ii) Xylene
iii) Methanol
iv) Permount
v) Meltmount nD 1.525
vi) Norland 65
vii) XAM

6) Hot Stage Microscopy
   a) Observe a demonstration of the software and the hot stage by your trainer. Make sure that you are familiar with the program ramp and how to capture images (if available on your system). Obtain known samples of various compounds that include inorganic and organic crystals (the Aldrich melting point standards set is an excellent place to start) and fibers (especially various types of nylon and polyethylene). In all samples that are run, make sure to note your observations throughout the run; such as fuming, sublimation, a change in birefringence, etc.
   b) Run each sample three times and record the melting point in a table. Since melting points may be shared by different compounds and may change depending on purity, they cannot be used solely for identification.
   c) Heat a sample of sodium nitrate to just above the melting point and make sure that the entire sample has melted. Ramp the temperature back down to room temperature and take photos when appropriate to mark the changes in the melt. Save the melt of sodium nitrate and use it for a reference of a uniaxial interference figure. After the sample has cooled look for any distinguishing properties in the melt (i.e. isotropic, anisotropic, uniaxial, biaxial, etc.) using a polarized light microscope and record the results.

4 MICROCHEMICAL METHODS

4.1 OBJECTIVES

- To familiarize the trainee with the theory and application of microchemical methods.
- To provide practical experience in using microchemical methods to the identification of unknown materials.

4.2 TOPIC AREAS

1. Using optical crystallography data in Winchell to determine compound identity
2. Introduction to microchemical methods of Chamot and Mason
3. Solubility and recrystallization
4. Microchemical reactions for common cations
5. Microchemical reactions for common anions

4.3 SAFETY

Tools for the manipulation of small particles are sharp and pose cutting and puncture-wound hazards. Care must be exercised in the use of fine tweezers, scalpels, tungsten needles, and other sharp tools. Refractive index immersion liquids may pose health hazards if there is skin/eye contact or ingestion.. Strong acids are corrosive on contact with skin.

4.4 SUGGESTED READINGS

1. Bloss FD. 1990. An Introduction to the Methods of Optical Crystallography. Marietta (OH): R.A.N. Publishers.
2. Chamot EM, Mason CW. 1944. Handbook of Chemical Microscopy. Vol 1. Chapters 9, 10, & 11. New York (NY): John Wiley & Sons.
3. Chamot EM, Mason CW. 1989. Handbook of Chemical Microscopy. Vol 2. Chicago (IL):McCrone Research Institute.
4. Feigl F. 1966. Spot Tests in Organic Analysis. 7th Ed. New York (NY): Elsevier Publishing.
5. Feigl F, Anger V. 1972. Spot Tests in Inorganic Analysis. 6th Ed. New York (NY): Elsevier Publishing.
6. Hollifield JM. 2003. Characterization of Squaric Acid Precipitates. The Microscope. 51(2):81-103.
7. Hopen TJ, Kilbourn JH. 1985. Characterization and Identification of Water Soluble Explosives. The Microscope. 33(1):1-22.
8. Lawrence G, Fink M. 2007. The Evaluation of Nitron Sulfate as a Microchemical Test for Some Common Oxidizers. The Microscope. 55(2):55-58.
9. MCrone WC, Draftz RG, Delly JG. 1967. The Particle Atlas. Ann Arbor (MI): Ann Arbor Science Publishers.
10. McCrone WC, McCrone LB, Delly JG. 1984. Polarized Light Microscopy. Chicago (IL):McCrone Research Institute.
11. Wills WF. 1990. Squaric Acid Revisited. The Microscope. 38:169.
12. Winchell AN, Winchell H. 1989. The Microscopical Characters of Artificial Inorganic Solid Substances: Optical Properties of Artificial Minerals. Chicago (IL):McCrone Research Institute.
13. Winchell AN. 1987. The Optical Properties of Organic Compounds. Chicago (IL):McCrone Research Institute.

4.5 STUDY QUESTIONS

1. Explain the difference between chemical spot tests and microchemical tests.
2. Explain Chamot and Mason methods I, II, III, and IX for microchemical testing.
3. What conditions must exist for microchemical tests to work properly?
4. Describe a method to differentiate ammonium ion from potassium ion.
5. Describe an analytical procedure to identify an unknown crystalline material using the methods of optical crystallography and microchemical methods.

4.6 PRACTICAL EXERCISES

1. Determine solubility of ten unknown samples.
2. Recrystallize ten known water soluble compounds and obtain photomicrographs of the resulting crystals.
3. Recrystallize sulfur from chloroform or other appropriate solvent and take photomicrographs.
4. Practice performing microchemical methods for common cations and anions suggested by your trainer based on the methods of Chamot & Mason, Hopen & Kilbourn, Hollifield, and others.
5. Measure optical properties (refractive indices, anisotropy, etc) of at least five unknown materials. Using tables from Winchell, develop a list of possible compound identities of each. Using microchemical methods from Chamot & Mason, Hopen & Kilbourn, Hollifield, and others, confirm the identities of the unknowns.

5 MICROSPECTROPHOTOMETRY

5.1 OJECTIVES

- To familiarize the trainee with the theory and application of microspectrophotometry.
- To familiarize the trainee with the microspectrophotometry instrumentation and software used in the laboratory.
- To have the trainee demonstrate how to properly interpret data generated by microspectrophotometry.

5.2 TOPIC AREAS

1. Chemistry and color
2. Instrument
    a. Components
        i. integrated microscope and spectrometer
    b. Operation
    c. Analysis Modes
        i. transmission
        ii. reflectance
        iii. fluorescence
3. Advantages & Limitations
4. Quality Assurance

5.3 SAFETY

Care should be taken to avoid looking directly at light coming from the lamps as eye damage can occur. The lamps also use high voltage power supplies that could result in serious electrical shock if contacted while on. They also generate significant heat so care should be taken not to make contact with them while in operation. Replacing the dust cover over the instrument should not be done until the lamps have cooled down. Do not open the housing or handle a mercury-vapor lamp housing while it is illuminated or hot; in addition to the possibility of burns there is always the danger of explosion.

5.4 SUGGESTED READINGS

1. Adolph FP, Dunlop J. 1999. Microspectrophotometry/Colour Measurement. In: Robertson J, Grieve, M. editors. Forensic Examination of Fibres. 2nd Edition. Philadelphia (PA):Taylor & Francis, Inc. p. 251-289.
2. Saferstein, R. 2007. The Microscope. In: Criminalistics: An Introduction to Forensic Science. 9th Edition. Upper Saddle River (NJ): Prentice Hall. p. 189-192.
3. User's manual for the specific instrument being used.

5.5 STUDY QUESTIONS

1. How does a microspectrophotometer work?
2. What range in the electromagnetic spectrum is used in microspectrophotometry?
3. List ways in which samples are prepared for microspectrophotometry?
4. What are some advantages of microspectrophotometry?
5. What are the limitations of microspectrophotometry?
6. How can microspectrophotometry be used to identify metameric colors?
7. How does sample thickness and sample surface morphology affect microspectrophotometry?

5.6 PRACTICAL EXERCISES

1. Analyze five red, yellow, blue, green, brown, and clear fibers of the same fiber type. Take ten scans of one fiber in each color group and then one scan each of the remaining four in each color group. Average the readings of the fiber you took multiples scans of and compare this average to the other four in that color group.
2. Analyze a red, blue, green and yellow paint sample by reflectance. Use high-gloss, non-metallic automotive paints. Using bright white auto paint as your reference, take five scans of each colored sample. Then using a semi-gloss and a matte paint as your reference, repeat the experiment for each color. Is there a difference when you use the different references? Which reference gives the best result? Why?
3. Analyze a red, blue, green and yellow paint sample by transmittance. Use high-gloss, non-metallic automotive paints. Take fine scrapings and smash/flatten them as best you can. Take at least five readings of each sample.
4. Compare the results of exercises 2 and 3 for each color. Which method gives the best results – transmittance or reflectance? Why?

6 EVIDENCE SCREENING AND EVALUATION OF TRACE EVIDENCE

6.1 OJECTIVES

- To instruct the trainee on how to properly screen trace evidence.
- Demonstrate the most appropriate techniques to separate and categorize trace materials.
- To instruct the trainee on trace evidence identification strategies.

6.2 TOPIC AREAS

1. Types of trace evidence seen in casework
2. Screening of trace evidence using the stereobinocular microscope in transmitted and reflected light.
3. Separation methods (e.g. density separation in water, filtering, sieving, tuning fork, sonication)
4. Evaluating the significance of trace evidence
5. Identification of common trace evidence types
6. Use of the polarizing light microscope in screening trace evidence
7. Examination of tape lifts
8. Use of mounting media
9. Additional resources - Slide mounted trace particles from the Criminalistics 101 practical exercises.

6.3 SAFETY

Use precautions when searching articles of clothing, sharp objects such as syringes, glass and knives may be concealed in fabric and pockets. Wear gloves and a lab coat when handling blood stained clothing.

6.4 SUGGESTED READINGS

1. Bisbing RE, Schneck WM. 2006. Particle Analysis in Forensic Science. Forensic Science Review. 18(2):119-124.
2. Palenik S. 1988. Microscopy and Microchemistry of Physical Evidence. In: Saferstein R. editor. Forensic Science Handbook, Vol. ll. Englewood Cliffs (NJ): Prentice Hall. p.161-208.
3. Schneck WM. 2009. Particles: Form. In: Jamieson A, Moenssens A. editors. Wiley Encyclopedia of Forensic Science. Chichester (UK):John Wiley & Sons Ltd. P. 2001-2007.
4. Houck M, editor. 2001. Mute Witnesses: Trace Evidence Analysis. San Diego (CA): Academic Press, San Diego.
5. Houck M, editor. 2004. Trace Evidence Analysis: More Cases in Mute Witnesses. Burlington (MA): Elsevier Academic Press.
6. Petraco N, Kubic T. 2004. Color Atlas and Manual of Microscopy for Criminalists, Chemists, and Conservators. Boca Raton (FL): CRC Press. Chapters 2, 5, 6, 14.

6.5 STUDY QUESTIONS

1. Define the following terms and describe their forensic significance:
    a. Hair – differences between animal and human
    b. Fiber
    c. Fabric
    d. Cordage
    e. Rope/twine/thread

f. Paint chip
g. Glass
h. Glitter
i. Soil
j. Lamp filament
k. Smokeless powder
l. Wood
m. Road beads
n. Metal turnings
o. Feather
p. Pressure sensitive tape
q. Botanicals (e.g. leaf fragments, seeds, grass, rootlets, needles)
r. Food particles
s. Insulation
t. Car seat foam
u. Dust
v. Insect parts
w. Sand
x. Makeup (e.g. lip stick, foundation, eyeliner)
y. Toothpaste

6.6 PRACTICAL EXERCISES

1. Characterize (sketch and photograph) particles in the Criminalistics 101 collection including materials from study questions above using stereomicroscopy.
2. Separate a vacuum sweeping sample into separate trace categories (e.g, fibers, hairs, paint chips, etc.).
3. Examine tape lifts for specific target fibers.
4. Examine isotropic and anisotropic minerals with stereomicroscopy using both transmitted and reflected light.
5. Examine debris scraped into a Petri dish from a pair of pants using stereomicroscopy. Add distilled water to cover the debris. Re-examine and describe the differences you see. What floated, what sank? Remove the floating particles and characterize by stereomicroscopy. Agitate the sample by swirling as a method to concentrate the dense particles. Filter the dense particles and characterize by stereomicroscopy.
6. Collect road debris from five different locations. Separate the samples and characterize with stereomicroscopy.
7. Using a piece of dry stained fabric, immerse in a beaker of distilled water. Sonicate and filter the debris.
8. Separate particles on paper using a tuning fork.
9. Characterize human hairs using visual and stereomicroscopic methods.
10. Characterize animal hairs using visual and stereomicroscopic methods.
11. Evaluate human hairs for DNA mito vs. DNA nuclear
12. Characterize and identify to class (e.g. hair, fiber, feather) 10 unknowns.
13. Examine the debris from two clothing items and write two practice screening reports.
14. Collect urban soil/debris from a curb. Place the sample in a beaker; add water and a clean magnetic stir bar. Stir for five minutes. Remove the stir bar and examine the collected particles. Characterize using a stereomicroscope.

7 INTRODUCTION TO BLOODSTAIN PATTERN RECOGNITION

7.1 OBJECTIVES

- To familiarize the trainee with the mechanisms of blood stain formation.
- To familiarize the trainee with the various types of bloodstain patterns that may be encountered in case work.
- To have the trainee demonstrate competence in performance of bloodstain presumptive testing.

7.2 TOPIC AREAS

1. Terminology
2. Mechanisms for dispersion of blood
3. Blood stains on various surfaces
4. Presumptive bloodstain testing

7.3 SAFETY

Exposure to blood and other body fluids carries the risk of exposure to blood-borne pathogens. Universal precautions should be exercised when examining items with potential blood-borne pathogens.

7.4 SUGGESTED READINGS

1. Bevel T, Gardner RM 2002. Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction. 2nd Ed. New York (NY):CRC Press. Chapters 1, 3, 4, 5, 7, 8, & 9.
2. Cox M. 1991. A Study of the Sensitivity and Specificity of Four Presumptive Tests for Blood. J. For. Sci. 36(5):1503-1511.
3. Eckert WG, James SH. 1989. Interpretation of Bloodstain Evidence at Crime Scenes. New York (NY): Elsevier, New York. Chapters 2 & 5.
4. Higaki RS, Philp WM. 1971. A Study of the Sensitivity, Stability and Specificity of Phenophthalein as an Indicator for blood. Can. Soc. For. Sci J. 9(3):97-102.
5. MacDonell HL. 1993. Bloodstain Patterns. 2nd Ed. Elmira (NY):Golos Printing.

7.5 STUDY QUESTIONS

1. What are the components in human blood?
2. How much blood is in a human body?
3. What is the difference between a bloodstain wipe and a swipe?
4. What microscopical tests/methods can be used to identify blood?
5. How can you determine how old a bloodstain is?
6. What are the differences between high, medium and low velocity impact patterns?
7. What is a ‘butterfly’ pattern on an item such as clothing?

7.6 PRACTICAL EXERCISES

1. Examine the following bloodstain patterns on the provided non-porous rigid material. Photograph and sketch each pattern and define each term. Record the orientation, location, size and position of bloodstains with respect to the material it is on.
   a. Passive drop
   b. Blood dripping into blood

   c. Splash
   d. Smear
   e. Wipe
   f. Swipe
   g. Cast-off
   h. Expectorated pattern
   i. Mist pattern
   j. Skeletonized Stain

2. Examine the following bloodstain patterns on the provided porous non-rigid material (fabric). Photograph and sketch each pattern and define each term. Record the orientation, location, size and position of bloodstains with respect to the material it is on. Describe what differences you can see between A and B.
   a. Passive drop
   b. Blood dripping into blood
   c. Splash
   d. Smear
   e. Wipe
   f. Swipe
   g. Cast-off
   h. Expectorated pattern
   i. Mist pattern
   j. Skeletonized Stain

3. Examine the provided clothing, bedding, tools and weapons for the presence of bloodstains. Document your observations using photographs and sketches and describe the types of patterns seen.

4. Perform phenolphthalein testing on various types of stains as specified by your trainer to determine specificity of the test and which substances may give positive results other than blood.

8 DAMAGE ASSESSMENT

8.1 OBJECTIVES

- To familiarize the trainee with the types of damage that may occur to clothing and/or other items of forensic significance.
- To familiarize the trainee with basic fabric construction.
- To have the trainee demonstrate a basic understanding of how to assess clothing for damage.

8.2 TOPIC AREAS

1. Fabric construction
    a. knits
    b. woven
    c. felts
2. Methods of Analysis
    a. visual
    b. alternate light source
    c. chemical testing
    d. stereomicroscopic
    e. other instrumental
3. Types of damage
    a. normal wear
    b. mechanical
        i. cuts
        ii. tears
        iii. stabs / puncture
        iv. abrasion
        v. blunt force
        vi. gunshot
        vii. explosion
        viii. insect
    c. thermal and chemical
        i. heat source, open flame, etc.
        ii. acid / base
    d. stains
4. Age of damage
    a. old vs. new
    b. laundered vs. unlaundered
5. Mechanism of damage
    a. origin
    b. motion / direction
    c. tears: one handed vs. two handed
    d. stains
        i. blood
        ii. other biological
        iii. paint
        iv. food
        v. cosmetics
        vi. other
        vii. side of origin
        viii. motion / direction
    e. other deposits
        i. botanical
        ii. glass

iii. other trace

6. Sample collection / preparation
7. Data interpretation and report writing

8.3 SAFETY

The creation of clothing damage test samples often involves using sharp objects, hazardous chemicals, and hazardous thermal sources. Appropriate protective clothing should be worn while conducting these experiments.

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8.5 STUDY QUESTIONS

1. Explain the difference between woven and knit fabrics.
2. What are the differences between new damage and laundered damage?

3. How are cuts differentiated from tears? What indicators are used to determine if the "weapon" was sharp or dull? How is directionality determined?
4. How is a scissor cut differentiated from a knife cut?
5. How can one determine what side of a material the damage has originated?
6. What differences are there between tears made with one hand versus two hands?
7. What are characteristics of burnt nylon? Silk?
8. What characteristics are indicative of insect damage and how are they observed?

8.6 PRACTICAL EXERCISES

1. Obtain a number of fabrics and other textiles which may commonly be encountered in forensic casework. The samples should include, but are not limited to, woven clothing items, knit clothing items, furniture upholstery, carpet samples, leather, and non-woven fabrics. Using notes, sketches, and photos the student will examine and characterize the provided samples. To the extent possible the student will describe the following for each sample:
    a. Construction (woven, knit, non-woven) If woven describe pattern. (1x1, 2x2, 3x3 etc.)
    b. Threads per inch in warp and weft direction
    c. Staple or continuous fibers in yarns
    d. Yarn twist
    e. Number of plies
    f. Direction of twist of plies
    g. Colors and design
    h. Blend of two or more types of fibers within each ply
    i. Sewing threads, buttons, decorations, etc.
2. Procure a number of used/worn fabrics and other textiles which may commonly be encountered in forensic casework. The samples should include, but are not limited to, woven clothing items and knit clothing items. If possible, used/worn furniture or vehicle upholstery and carpet samples should be included. Using notes, sketches, and photos characterize the defects observed in the provided samples.
3. Prepare test damage by using various "weapons" (to include but not limited to; single edged knives, double edged knives, scissors, box cutters, ice picks, screw drivers, etc.) on the fabrics and textiles collected for exercises 1 and 2. The damage should include cuts, tears, punctures, stabs, slashes, etc. In addition, gunshot damaged articles obtained from the firearms section should be evaluated. Using notes, sketches, and photos characterize the provided samples and articulate the following:
    a. All information derived from the examination of the defect (type of weapon, how used, etc.)
    b. The class and individual characteristics encountered in the samples examined.
    c. The problems encountered in the examinations of the materials and how they can be overcome.
    d. The best methods for documenting the examinations.
    e. The significance of their findings.
    f. Additional analysis that can be/should be performed.
    g. The wording of their report.
4. Obtain several t-shirts. Using a volunteer, tear a t-shirt by pulling with one hand, and tear another t-shirt using two hands. Observe and record the damage.
5. Place the damaged articles from exercises 3 and 4 in the laundry and reexamine them after they have been dried, documenting and noting differences between the pre- and post-laundered damage.
6. Procure a number of fabrics and other textiles of known composition which are commonly encountered in forensic casework. The samples should include the following fiber types: cotton, rayon, silk, linen, wool, acetate, acrylic, olefin, nylon, and polyester.
    a. Expose small sections (~5mm x 5mm) of the material to an open flame by holding it approximately ¼ to ½ inch from the flame of an alcohol burner.

b. Expose the known materials to a variety of chemicals including sulfuric acid, acetic acid (vinegar), sodium hydroxide (lye), and ammonia.
c. Obtain insect damaged items if available.
d. Record observations of both visual and stereomicroscopic examination of the materials.

9 PHYSICAL MATCH

9.1 OBJECTIVES

- To familiarize the trainee with some of the possible types of rigid objects, pliable objects and continuous roll objects that may be subject to physical match examinations.
- To practice several methods which can be used for documentation of a physical match.
- The trainee will be able to understand and articulate why some objects do not lend themselves well to a physical match.

9.2 TOPIC AREAS

1. Introduction
   Physical Match evidence can be of great value in criminal investigations. The ability to definitively link specific items, to the exclusion of all other like items, is virtually unique in the field of forensic science. Despite the potential value physical match, also called fracture match examinations, can easily be overlooked by investigators. The collection of evidence for this type of examination often requires meticulous searches looking for extremely small particles. Likewise, an examiner in the laboratory must have a logical scheme of examination whereby the possibility of a fracture match is one of the first considerations.
2. Fracture Match of Rigid Materials
   a. Normal fracture match examinations and comparisons involve the direct comparison of broken, torn or cut edges against the comparable edges of a second item. This examination may be done with the naked eye or may require the use of magnification such as a stereomicroscope.
   b. Care must be taken to ensure that the individual pieces can be identified as to the item from which they came. This is most easily done by marking the pieces as they are examined. If the item is too small or the nature of the item precludes this, then detailed notes, sketches, and/or photos must be taken so that the source of each individual piece can be identified.
   c. Commonly encountered rigid items in fracture match examinations can come in all sizes, ranging from a small paint chip or piece of wood to large vehicle parts. Additionally, the items examined may be fragile, which may present problems associated with the actual comparison procedure. Care should be taken to avoid altering the item during the examination.
   d. In some cases an actual fracture match may not be possible, but the examination may still produce significant results. Sanding striations on the bottom of a paint chip, decals, stains, inherent design elements, and wood grain patterns are examples of features which may lead the examiner to infer an association between two items even if intervening pieces are missing. This association may fall sort of the significance of a fracture match but may still be beneficial to the whole case.
3. Fracture Match of Pliable Materials
   a. Commonly encountered pliable items in fracture match examinations can come in all sizes and compositions.
   b. Pliable items such as plastic films can be stretched or otherwise deformed in the process of being torn or cut.
   c. Paper matches torn from a matchbook often have a torn edge which is not sufficiently unique for comparison purposes. In these cases the examiner must rely on the comparison of individual fibers or other fillers in adjoining matches. Small paint chips and bits of paper are often compressed into the matches during the manufacturing process. If these particles are cut through leaving corresponding pieces in adjacent matches, a fracture match can be inferred even though the actual torn edge is unremarkable.
   d. A blank piece of paper that is cut can pose problems for the examiner which may preclude a definitive associate. However, papers such as pieces of newspaper are generally quite easily compared.

4. Fracture Match of Continuous Roll Materials
    a. There are generally two types of comparison which may be encountered in continuous roll products.
        i. The attempt to associate of cut or torn sections of the product.
            1. This examination proceeds like most fracture match exams in that one looks for a unique correspondence of the cut or torn edges.
        ii. The attempt to associate two items which may have once been continuous, but were separated either during the manufacturing process of during normal use, such as paper towels separated at the perforations.
    b. Continuous roll products come in many forms, some of which are not initially recognized as a continuous product.
        i. Plastic garbage bags are produced as a continuous roll product but are often separated into individual components during the manufacturing process. A box of this type of product may contain sequentially produced bags which at one time were joined, but likely will also contain bags which are out of sequence. In some instances, the bags may show “striations” when viewed with backlighting. These are generally caused by the slight variations in the thickness of the film. These can be used to associate two individual bags or to associate two or more sections of the same bag.
        ii. With items such as torn tapes, especially duct tape, it is generally fairly easy to establish a correspondence based solely on the torn edges, although stretching can pose some problems. However, the tapes are cut, the comparison will likely focus on the correspondence of the class characteristics and their relationships in the individual items.
            1. Duct tapes vary greatly in their construction. Some tapes exhibit very straight threads across the width of the tape and along the length of the tape while others exhibit fibers that undulate in an irregular pattern. A cut tape with irregular thread spacing may lend itself to a positive association based solely on the correspondence of these aligned threads.
        iii. The examination and comparison of cut wire generally focuses on the correspondence of class characteristics such as extrusion marks on the wire and/or the plastic insulation.
        iv. Items such as paper towels may be associated based on the correspondence of the printed or “dimple” patterns.

9.3 SAFETY

Rigid, brittle materials may have sharp edges and should be handled with caution.

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9.5 STUDY QUESTIONS

1. What is a class characteristic? What is an individual characteristic? Give examples of each.
2. What things should be considered when collecting and packaging physical evidence which may be the subject of physical match examinations?
3. What is a direct physical match? What is an indirect physical match? Give examples of each.
4. What is a striation? Give some examples of striation marks?
5. You have determined that a physical match exists between two pieces of black electrical tape. The ‘match’ is a straight diagonal cut across the tape. What would be the differences between this example and one in which a jagged tear is matched between two pieces of duct tape? What additional analysis could be performed?
6. How many points of comparison if any, are needed to call two juxtaposed items a physical match?
7. How would you document a physical match in your notes?
8. What are tool marks?

9.6 PRACTICAL EXERCISES

The trainer will procure rigid items which are commonly encountered in forensic casework. The items should be torn, broken and/or cut into pieces suitable for examination. The total number of items examined will be determined by the trainer. The trainee will use a combination of notes, sketches, and photography to document their examination and any physical matches which may be identified. The trainee should be able to articulate:

- The class and individual characteristics encountered in the samples examined and how they may help or hinder examinations.
- The problems encountered in the examinations of the materials and how they may be overcome.
- The best methods for documenting the examinations.
- The significance of their findings.
- Additional analysis that can be/should be performed.
- The wording of their report.

1. Rigid materials: These should include, but are not limited to: wooden sticks or rods, paint chips, glass, metal pipe and vehicle parts such as lens elements or grill pieces.

2. Pliable items: These should include, but are not limited to: plastic films such as ziplock type bags, paper, paper matches, and cloth/clothing.
3. Continuous roll products: These should include, but are not limited to: duct tape, electrical tape, trash bags, and paper towels.

SECONDARY FOUNDATION MODULE 1 CHECKLIST				
Trainee:		Trainer:		
		Trainee Initials/Date	Trainer Initials/Date	Time for Completion
Advanced Microscopy				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Special Applications				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Microchemical Methods				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Written Exam				

SECONDARY FOUNDATION MODULE 2 CHECKLIST

Trainee:		Trainer:		
		Trainee Initials/Date	Trainer Initials/Date	Time for Completion
Microspectrophotometry				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Written Exam				

SECONDARY FOUNDATION MODULE 3 CHECKLIST

Trainee:		Trainer:		
		Trainee Initials/Date	Trainer Initials/Date	Time for Completion
Evidence Screening & Evaluation of Trace Evidence				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Introduction to Bloodstain Pattern Recognition				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Damage Assessment				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Physical Match				
	Reading			
	Demonstration/observation			
	Study questions			
	Practical exercises			
Written Exam				
Competency Testing				
Co-Signed Cases				

Case Number	Findings	Co-Signer