Forensic microscopy: An exciting field

Gary Laughlin

Forensic microscopists are scientists who specialize in the investigative use of microscopes. Contrary to popular belief, they do not solve crimes alone, but they do establish facts in an attempt to contribute to the solution of crimes and chemical problems. It is the forensic microscopist’s job to learn how to master his or her instruments and make detailed observations, measurements, and recordings of the microscopic trace evidence that is usually available in criminal and civil litigation. The forensic microscopist’s findings may provide valuable clues, lead investigators to a criminal or crime scene, exonerate or implicate suspects, or solve an otherwise unsolvable problem.

Despite the recent popularity of American television programs like CSI: Crime Scene Investigation, some may be surprised to know that forensic microscopy is not a new scientific field. Public awareness that there may be something useful was greatly increased in 1887 when Arthur Conan Doyle introduced his fictional character Sherlock Holmes. During this time, a number of his nonfictional contemporaries were relying heavily on chemistry and microscopy and applying them to the study of blood and semen spots. They were also performing comparisons of hairs, dust, and soil. The famous Austrian criminalist Hans Gross wrote in his 1893 manual on criminalistics: “Dirt on shoes can often tell us more about where the wearer of those shoes had last been than toilsome inquiries.” Since then, there have been many criminalists known for their amazing ability to use the microscope to find, interpret, and analyze evidence that otherwise might be overlooked. But none of their success could be acquired without the proper skills, training, practice, experience, and scientific equipment.

The polarized light microscope

Because forensic microscopy is not taught as a scientific discipline, the ideal way to become a forensic microscopist is to self-start with the light microscope, the polarized light microscope (PLM), and then advance to more formal training in microscopy courses. The PLM is similar to an ordinary compound microscope except that it is equipped with a rotatable stage, polarizer, analyzer, Bertrand lens, and compensators that are used to observe and document optical properties primarily due to the anisotropy of specimens. A proper PLM allows one to determine shape-dependent and optical properties in unpolarized, plane-polarized, or crossed-polarized light (crossed polars).

The training for a budding polarized light microscopist should include learning how the microscope functions. This includes understanding basic physical optics, proper microscope alignment, Köhler illumination, and micrometry. This should be followed by the careful study of microscopic particles including human and animal hair, synthetic fibers, glass, plant particles, soil, paint, metals, plastics, insect parts, and substances of all types. A well-trained forensic microscopist can identify and distinguish common household chemicals (sugar, salt, baking soda), food products, toothpaste, talcum powder, lint, sand, and dust. They will need to learn how to characterize, identify, and compare the microscopic traces that materials leave behind and are transferred when they are moved, contacted, or disturbed. This is the theoretical basis for forensic microscopy that has become known as Locard’s Exchange Principle: “Whenever two objects come into contact with one another, there is always a transfer of material between them.” This transfer of material is evidence of direct contact and is, more often than not, microscopic in size and quantity.

Forensic microscopists traditionally come from diverse backgrounds that include academic training in the fields of chemistry, physics, biology, geology, and materials science. But usually they start out with an uncommon general curiosity about the microscopic world around them. The need to increase that knowledge is further satisfied by continued self-study and by taking intensive training courses in microscopy, like those offered at the McCrone Research Institute in Chicago, specializing in applied polarized light microscopy, microchemistry, plant anatomy, mineralogy, and crystallography. There is no limit to the number and variety of particles that can be studied with the microscope. A brief description of selected trace evidence categories follows.

Hairs and fibers

Fibers are the easiest particles to master and are quite distinctive when studied microscopically. Using morphology (shape) and composition-
dependent optical properties such as refractive index, birefringence, and signs of elongation, a trained microscopist can easily determine the fiber category almost instantly, at sight, and immediately place it into a category of synthetic, natural, or glass, including fiber blends and mixtures of every conceivable type: asbestos, metal, wood, rubber, paper, fur, etc. Hairs, of course, are easily recognized as fibers, and as hairs, by their microstructure (presence of scales, pigment, etc.) that allows for categorization as human or not and oftentimes individual species. Human head hair averages about 100 micrometers in diameter. Hair and fiber microscopists can quickly scan fiber evidence and do preliminary identification and comparison of hairs and fibers prior to more time-consuming and costly hair comparison and DNA analysis.

**Glass**

Glass particles are easily produced and transferred as a result of accidental breakage and certain criminal behavior. Glass evidence is often present as a result of automobile collisions, forced building entries, and physical assaults involving broken glass containers, tableware, or windows. Glass evidence is examined and often compared using morphology, optical properties (refractive indices, dispersion, etc.) and chemical composition to determine origin and the probable or improbable identity of a source.

**Explosives**

Explosives and related ingredients may come to the forensic microscopist as a powder, bulk explosive, or an explosive or pyrotechnic residue after a bombing. It is possible to use microchemical methods to identify some of the ingredients. For example, water-soluble nitrates are a common constituent of certain explosive devices and fertilizer. A few nanograms of suspect material can be dissolved in a drop of solvent while a small crystal of nitron sulfate reagent is dissolved in a second droplet. Then, the two droplets are drawn together. The formation of radiant, birefringent needles precipitating from the mixture indicates the presence of nitrates. Military, commercial, and homemade explosives are identified in a short period of time using PLM, microchemistry, optical crystallography, and microscopical fusion methods.

**Soil, dust, and sand**

The usual purpose of a microscopical soils analysis is the study of two or more soil samples for possible common origin. Soils are more difficult to study than, for example, fibers and glass and require familiarization with optical mineralogy, crystal morphology, and petrography. Nearly all soils, sand, and dust are mixtures of dozens of different components (not all mineral) with a large number of identifying characteristics that are ideally suited for PLM. Sand particles are recognized microscopically as being the result of water-worn (beach, river, lake, etc.) or wind-worn (desert) erosion and potentially can be sourced to a precise geographic location.

**Paint and coatings**

Paint from automobiles, architectural and decorative coatings, in addition to works of art, may produce microscopic chips and fragments when disturbed. Microscopic spray-paint particles are also produced during paint application and spraying operations. These types of particles are easily transferred and may be used by the forensic microscopist as evidence. From a microscopic examination it is possible to determine the composition and identity of the paint for comparison to suspect sources and common origin. Paint chips are physically compared for physical matches (color, layering, and thickness), whereas the paint pigment, extenders, and medium are identified microscopically and microchemically. Forensic microscopists that study paint and decorative coatings (including cosmetics) can determine the origin and authenticity of some pigments based on their historical availability. For example, red ochre dates to before 1300 AD, and has been found in prehistoric cave paintings; titanium white dates to 1916 AD. Knowing the chemical identity assists in the determination of the possible date of creation and contributes to the efforts of art restoration and preservation.

**Drugs**

Illicit, pharmaceutical, and over-the-counter drugs and drug products are ideally suited for microscopical analysis. Forensic microscopists are sometimes asked to do nonroutine analysis of drug evidence, check for various classes of drugs, and identify particular drugs substances and ingredients. The drug chemist uses the microscope to determine identity by utilizing crystal morphology and optics, microscopical fusion methods, microcrystal tests, and microchemical tests.

**Building materials**

Building and construction material particles are commonly produced during forced entry into buildings and may be transferred from crime scene to suspect and then again to the suspect’s belongings. The majority of dust created during the September 11, 2001, attack on the World Trade Center in New York was disintegrated building material, concrete,
building insulation, etc. Many building materials are mixtures of fibers, coatings, and fillers including paint, minerals, glass, vermiculite, asbestos, and other binders and extenders. A large number of polarized light microscopists have been trained in the examination of building materials, especially in the determination of the presence or absence of federally regulated fibers and hazardous dust, such as asbestos, used in building insulation, automobile brake pads, and mining products.

**Botanicals**

Particles from plants (wood, linen, cotton, cereal grains, starches, flour, food products, etc.) are best studied microscopically with the light microscope. These include plant cells of all varieties, pollen, mold, and fungal spores. Aerobiologists, industrial hygienists, and indoor and outdoor air-quality specialists practice forensic microscopy when they begin to establish facts about the presence or absence of certain microscopic particles such as fungal spores and other irritants that are identified in air or settled dust samples.

**Food and food contaminants**

Forensic microscopists are sometimes asked to perform investigations on food and other commercial products. These are usually submitted in the case of consumer complaints, tampering investigations, and product identification of unknown substances. Microscopists working in food research, new product development, competitive analysis (a.k.a. industrial espionage) or contamination control use forensic microscopy techniques for the microscopical examination of foods. They are frequently asked to determine the identity of food plants, cereal grains, starches, sugars, flours, doughs, premixes, leavening agents, meats, fats, waxes, and oils. “Foreign body” contamination and source determinations are performed microscopically on a variety of particles. It is not uncommon to find glass, paint chips, hair, insect parts, and other undesirable “blemishes, specks, and filth” on (and in) suspect food products.

**Suspicious powders: Counterterrorism and homeland defense**

As a result of the anthrax scares of 2001, forensic microscopists in local and federal laboratories have been asked to analyze a new type of evidence: suspicious “white powders.” Forensic “white powder” microscopy is currently being taught to these and other scientifically and medically staffed hazardous material and U.S. military civil support teams. This is in an effort to assist in the determination of the identity of substances having the potential to be used as explosive, chemical, or biological weapons. The PLM, in conjunction with DNA fingerprinting, culturing, antibody tests, polymerase chain reactions, chemical tests, and spectroscopy, assists the analysts in the examination of the physical evidence. It allows for the rapid characterization and identification of a wide variety of substances. This includes those that might be mistaken for chemical or biological agents used mischievously as “white powder” hoaxes. Ordinary cornstarch, not anthrax, was used in a recent white powder scare.

With polarized light microscopy, it should be easy to see why forensic microscopists today, as they have in the past, are able to make such impressive contributions to the solution of their cases.

**Netlinks**

www.mcri.org
www.aafs.org
www.forensics.ca

Gary J. Laughlin is a forensic microscopist and instructor with the McCrone Research Institute (McRI) in Chicago. McRI is an independent, not-for-profit corporation founded in 1960 and dedicated to teaching and research in applied microscopy. He can be contacted at: glaughlin@mcri.org.

**Microscopy resources**

The AOCS Feed Microscopy Division offers programs and resources on the various aspects of microscopy, which includes sessions at the AOCS Annual Meeting each spring and an annual short course in the summer (netlink: www.aocs.org/meetings for information). In addition, the division has developed methodology for analysis of feedstuffs, the Manual of Microscopic Analysis of Feedstuffs, 3rd Edition, available from AOCS Press (netlink: www.aocs.org/catalog).