Forensics applications with Phenom desktop SEM

The Phenom desktop SEM combines the best of the optical and electron optical world. The Phenom provides useful images up to 45,000x magnification with high depth of focus. It is as easy to use as a typical laboratory-grade optical microscope and is therefore accessible for any forensic examiner in the lab.

Every forensic laboratory contains a number of optical and digital microscopes. This is one of the primary requirements when setting up a forensic laboratory to perform routine imaging tasks. In general, these optical devices are robust and easy to operate. However, the demand for magnifications beyond the optical range (>1000x) is increasing as the features of interest become smaller. Scanning Electron Microscopy (SEM) can go beyond the optical scale with very high magnifications and depth of focus. Another advantage of SEM is the possibility to perform elemental analysis of microstructures. Combined with electron imaging, X-ray analysis is a very powerful tool for understanding the composition and structure of materials.

To step up from an optical device to a traditional SEM can however put a large dent in the budget of a forensic laboratory. Besides the considerable system investment, it requires special lab facilities and a dedicated trained operator.

The use of SEM in the forensic market can be of great value. The diversity of samples and applications is broad. The Phenom can investigate the majority of these samples. Some of the key applications are listed below.

**Gun Shot Residue (GSR)**

GSR is the residue deposited on and around the body of the shooter after a bullet has been fired. Detection of a significant amount of residue, therefore, is a powerful piece of forensic evidence that the particular person was very near to or even holding the gun when it discharged. Particles containing lead, antimony and barium are considered characteristic of traditional GSR. The most definitive method for determining whether a particle is characteristic of or consistent with GSR is by its elemental profile. Particle analysis made by the Phenom proX desktop SEM with an energy-dispersive X-ray spectroscopy detector (EDS) can be the most powerful tool for forensic scientists in establishing proximity to a discharged firearm and/or the contact with a surface exposed to GSR.

The image shows a potential GunShotResidue particle (6400x magnification). GSR particles can quite easily be recognized based on compositional information from the Phenom back scatter detector. The particle can be further analyzed by using the Phenom’s Energy Dispersive X-Ray Detector (EDS).
**Traffic accidents**

Scanning electron microscopy is often used to investigate forensic evidence where a traffic incident has resulted in serious injury. With the Phenom desktop SEM, forensics investigators can easily image a light bulb filament and perform elemental analysis. If a vehicle headlight, rear light or indicator was on at the time of an accident, the lamp filament would be hot and glass particles would melt onto it. Different glass particles can be shown and analyzed with the desktop SEM and used as evidence when investigating causes of accidents.

The safety belt of a car will reveal whether or not it was in use during the moment of impact. Animal hair found on the vehicle could point to the cause of a collision. Car paint flakes can be very useful in providing evidence of hit and run accidents.

This screenshot shows the Phenom EDS spot analysis results from the particle in the form of spectrum peaks and an output table containing the elements and weight percentage. The particle is identified as (traditional) gunshot residue due to the presence of Lead (Pb), Antimony (Sb) and Barium (Ba).

This screenshot shows an EDS analysis of gun powder (gun: dagx 9x19 np). Both the police in the Netherlands and in Germany use Gadolinium in their gun powder for easy recognition. The electron image is shown top right. The Gd peak can clearly be seen in the spectrum at 6.056 keV. The weight percentage is also displayed in the output table (3.6%).

This screenshot shows the Phenom image and elemental analysis of a light bulb. When a car head- or rear light or indicator is on, the lamp filament becomes hot and at the time of a crash glass particles will melt onto the filament. EDS spot analysis from the highlighted position (spot 1) inside the image clearly shows the presence of SiO2 (glass). The other 2 particles that can be seen attached to the filament have the same gray level as the identified glass particle and can be considered as glass particles as well. Material contrast based on gray level is very powerful when imaging with the back scatter detector.
Small car paint flakes can often be found at the crime scene following a hit and run accident. Car paint consists of different layers. Comparisons are made between flakes from a suspect vehicle and the specimen in order to find a match.

The picture shows a paint flake revealing various paint layers. The numbers represent the positions where a spot mode analysis has been made.

The screenshot shows an overview of a car paint flake that has been mapped. Elemental mapping reveals the distribution of the different elements within the sample. The different elements can be highlighted by coloring.
Animal hair found in a car could be the cause of a so called “one vehicle” accident. Hairs are composed primarily of the protein keratin and can be defined as slender outgrowths of the skin of mammals. Each species of animal possesses hair of a characteristic length, color, shape and root appearance, and internal microscopic features that distinguish one animal from another. The images above were taken using the charge reduction sample holder which makes it possible to image non-conductive hair in its original state (no sputter coating is required).
**Crime scene investigation**

If a crime scene contains microscopic samples such as hair, diatoms or pollen, these can be easily identified using electron microscopes.

Diatoms and pollen analysis can be useful in forensic science by helping identify the provenance of individuals, clothing or materials recovered from investigation sites. Forensic hair analysis can be of crucial value in a criminal investigation when identifying criminal suspects and victims or when associating them with a specific location. Hairs can be transferred during physical contact; their presence can associate a suspect to a victim or a suspect/victim with a crime scene. Comparison of the microscopic characteristics of questioned hairs to known hair samples helps determine whether a transfer may have occurred.

**Hair**

Forensic hair analysis can be used for:
- Identifying criminal suspects
- Identifying crime victims
- Associating a victim or suspect with a location
- Determining the type of crime committed

Hairs can be transferred during physical contact; their presence can associate a suspect to a victim or a suspect/victim to a crime scene. The types of hair recovered and the condition and number of hairs found all impact on their value as evidence in a criminal investigation. Comparison of the microscopic characteristics of questioned hairs to known hair samples helps determine whether a transfer may have occurred.

In humans, hairs found on the head, pubic region, arms, legs and other body areas have characteristics that can determine their origin. Most information can be derived from head hair. Differences in cross section, the outer layer (cuticle), central canal etc. can indicate the person’s origin (African, European, Asian).

Hair of European (upper) and Asian (lower) origin including a point-to-point measurement made with Phenom.
**Biological evidence**
Diatoms are unicellular organisms that live in open water. Diatom analysis can be of further use in forensic science by identifying the provenance of individuals, clothing or materials from sites of investigation.

In cases of drowning, the inhalation of water causes penetration of diatoms into the system and blood stream, and thus their deposition into the brain, kidneys and other organs. If the victim was dead before the body was submerged, the transport of diatom cells to various organs is prevented because of a lack of circulation.

The type of diatoms that have been found can be used to pinpoint the location at which the drowning occurred. The presence of specific diatoms in the cloth of a body can reveal whether a body has been moved.

Diatoms generally range in size from approx. 2-200 μm which can make it difficult to recognize them using light microscopy. A desktop SEM is the perfect solution due to its higher magnification and depth of focus. Sample preparation is similar to that used with optical devices.
Pollen is a fine to coarse powder containing the microgametophytes of seed plants. Pollen grains come in all shapes and sizes and never decompose. Pollen can tell a lot about where a person or object has been because specific locations can have a distinctive collection of pollen species. Pollen evidence can also reveal the season in which a particular object picked up the pollen. For instance, a dead body may be found in a wood, and the clothes may contain pollen that was released after death, but in a place other than where the body was found. That indicates that the body was moved.
**Mechanical evidence**

Most crimes are committed using tools such as knives, crow bars, screwdrivers and wire cutters. When criminals use these tools to commit a crime, they can leave behind marks or damage to the material they come into contact with. The marks made are generally lines (called striations) and are caused because of imperfections on the surface of the tool.

Cutting fibers with a knife will be different from cutting with a pair of scissors. Gunshots will also damage the fibers in a specific way.

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Fiber ends from textile which have been cut by a knife.

As shown on the left, the back scatter imaging detector inside the Phenom can be used in 2 modes:

1) Compositional mode (full mode). This gives maximum signal resulting in material information by means of contrast differences. Different materials can be recognized based on the gray scale level (left side image).
2) Topographical mode. This gives a different kind of shading resulting in a topographical image (3D effect). This mode makes the surface structure more clearly visible.
Asbestos
In the 20th century, asbestos was often used in construction materials. Forensic investigation of suspected asbestos-related deaths includes a life-time occupational history, a complete autopsy, and identification of the asbestos fiber tissue burden.

The screenshot shows the Phenom EDS analysis results from crocidolite, also known as “blue asbestos”.

Blue asbestos

Other SEM applications in forensics:
• Classifying minerals in soil
• Detection of small pieces of bone in debris
• Analyzing explosive residues
• Examining micro-traces of foreign material in forensic pathology and anthropology

Phenom-World
Phenom-World offers a wide range of desktop-based electron microscopes and accessories. The Phenom-World products are intuitive to use, fast to create results and built to high quality standards. From the entry level pure series through to the high-end pro series, all Phenom electron microscopes share ease of use, unmatched time to results, and worry-free system ownership.

The Phenom desktop SEM is a true walk-up tool for many forensic experts who investigate their own samples in first line. Forensic applications of SEM are found mostly in areas where there is a need for good imaging at high magnifications in combination with elemental analysis. This is the case in areas where small particles of relatively heterogenic character and with a complex composition play a major part, for example gunshot residue, and pyrotechnical post-explosion residues.

These analysis can be accomplished with the Phenom proX desktop SEM – a powerful all-in-one electron microscope with fully integrated EDS technology. The Elemental Identification software available for the Phenom proX allows researchers to program multiple point analysis and identify any hidden elements within any sample.