B147 Cathodoluminescence Microspectrophotometry in Forensic Science

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The goal of this presentation is to provide an introduction to the principles and practice of cathodoluminescence with a specific focus on the visual and spectroscopic information that can be obtained from forensic samples and the applicability of CL to cases of comparison, authentication, and provenance.

Cathodoluminescence (CL) is a microscopical technique applicable to a range questions involving the forensic analysis of trace evidence. The visual and spectroscopic information provided by CL microspectrophotometry will impact the forensic science community by aiding in the comparison, authentication, and provenance examinations of forensic materials including soil, building materials, paints, duct tape, and glass.

Cathodoluminescence (CL) is the emission of visible or near visible light from a sample that has been bombarded by an electron beam. CL results from the alteration of band-gap energies due to the presence of trace elements or structural defects in crystalline materials such as minerals. The CL emission is characteristic of either the geological environment of formation of the mineral or, for a synthetic luminescent material, the manufacturing process. CL is observed in many materials routinely encountered as trace evidence, including soils and rocks, building materials, glass, pigments, and filler/extenders. The variation in luminescence for a particular mineral can therefore be used to discriminate among samples from different sources or, in certain cases, provide information about the provenance of a sample.

Many of the most abundant minerals (e.g., quartz, feldspar, and carbonate minerals) are cathodoluminescent. Due to their ubiquitous nature, these mineral components have typically been underutilized for forensic discrimination. However, the variation in luminescence within a given mineral type provides additional discrimination among sources and offers the potential for improving the significance of geological evidence. Prior research has demonstrated that cold cathode CL with light microscopy provides a relatively fast method to screen soil samples through visual identification of luminescent minerals, the ability to determine if multiple populations of a given mineral type exist, and a means to estimate the relative abundances of luminescent minerals in a sample. Surface information including zoning, textures, and coatings can also provide information about the origin of a sample. For minerals such as quartz, the visible luminescence color can be broadly correlated with a geological formation condition (e.g., metamorphic, volcanic, authigenic).

In addition to visual observation, high-resolution CL spectroscopy can offer more detailed information about specific activators (defects and trace elements responsible for luminescence) in a given mineral. For example, in feldspar minerals, the chemical composition can be estimated on the basis of the Fe^{3+} emission band. In heavy minerals such as zircon, monazite, and apatite, rare earth element activators, typically present at 1-500 ppm, can be identified and quantified with high resolution spectroscopy. Together, visual and spectroscopic examination of mineral components can be combined to provide a variety of information about soil and sand samples that complement more traditionally used analytical techniques. CL can also provide an additional discrimination factor for trace evidence by adding time- resolved high-resolution spectroscopy. Electron bombardment of the luminescence minerals will often alter the crystal structure or defects within it, which will cause the luminescence to change with time. The rate with which this luminescence for a material typically decreases in intensity, as well as shifts in the position of some broad spectral emission peaks, allows another method to discriminate between samples and provides additional information about provenance.

This presentation will provide an introduction to the principles and practice of CL with a specific focus on the spectroscopic information that can be obtained from geological samples and the applicability and limitations of CL in cases of comparison, authentication, and geographic sourcing. Spectroscopic information will be compared with prior data collected using visible luminescence imaging to assess the degree of additional discrimination and value to provenance determination offered by high resolution spectroscopy.

Cathodoluminescence, Geology, Soil

