

## SEM-Cathodoluminescence Imaging and Spectroscopy - Applications in Archeology and Life Science

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Scanning electron microscopes (SEMs) are widely used as an imaging technique for any solid materials found on Earth. Newly synthesized materials, frozen biological samples, and geological and ancient materials can all be studied by SEMs. SEM-based spectroscopies, such as energy dispersive X-ray spectroscopy (EDS) and cathodoluminescence (CL), are applied to study the composition and structure of various samples. SEM-CL imaging and spectroscopy detect the emitted photons in the visual range. The luminescence results from band transitions can be related to different material properties, such as band gap, crystallinity, impurities, and defects in the structure.

We have been using SEM-CL as an imaging and spectroscopy tool in different fields, including less-studied ones such as archeology and life science. CL spectral measurements of CaCO<sub>3</sub> samples were performed as part of research in archeology, and the CL imaging of cholesterol crystals was implemented as part of a complete workflow to study their 3D structure.

Materials such as calcium carbonates (CaCO<sub>3</sub>) found in archeological excavations can be studied with SEM-CL as their intrinsic defects and dopants create luminescent centers that can be detected. The various forms of CaCO<sub>3</sub> have unique defects that can be revealed by detecting the luminescence of the crystals. SEM-CL was used to study CaCO<sub>3</sub> in different forms: calcite and aragonite, which nucleate through geogenic and biogenic pathways, and pyrogenic lime plaster. The structural variations in CaCO<sub>3</sub> from various origins were measured by SEM-CL and correlated with radiocarbon dating (1-3). Using SEM-CL and complementing it with other analytical techniques, we formed a database of CaCO<sub>3</sub> samples from different sources. This database is of great importance in identifying the form of CaCO<sub>3</sub> when sorting materials from archeological excavations and increasing the accuracy of age determination by carbon dating.

SEM-CL of organic materials is quite challenging as their luminescence decay very fast under the irradiation of the electron beam. Cholesterol crystals are CL active and stable enough to be detected and imaged. Cryo SEM-CL was used as a first step in a correlative workflow that was developed to study atherosclerotic lesions in three dimensions at the nanometer scale. The cholesterol crystals and lipid droplets, both luminescence active, were identified by CL imaging. Following the CL imaging, the crystals were identified

using SEM and moved to the FIB-SEM for volume imaging, all done under cryo conditions. The results of this workflow show that thin crystals appear to be associated with intracellular or extracellular lipid droplets and multilamellar bodies. The large crystals are independently positioned in the tissue and are not associated with specific cellular components (4).

In summary, SEM-CL studies of CaCO<sub>3</sub> samples and cholesterol crystals revealed the opportunity to use this method to explore materials and systems in fields such as life science or archeology.

**Keywords:**

Cathodoluminescence, SEM, Cryo, CaCO<sub>3</sub>, Cholesterol

**Reference:**

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