Table-top Cathodoluminescence Microscopy for Geology

Toon Coenen
Business unit owner CL solutions
coenen@delmic.com

Prof. Albert Polman
Dion Ursem
Hans Zeijlemaker

Thomas van der Heijden
Sudiksh Srivastava
Dorus elstgeest
Wouter Roelofsen
Andries Effting
Sander den Hoedt

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Cathodoluminescence system on floor model SEM

Example of a state-of-the-art CL system on a floor model scanning electron microscope (SEM)
Floor model SEM-CL data examples

- Panchromatic CL map zircon
  - H. J. Kjøll (Uni. Oslo)
  - 30 μm

- Hyperspectral map zircon
  - C. Fan (Beijing Geoanalysis)
  - 25 μm

- CL spectrum sapphire
  - J. Wong (Uni. Queensland)
  - Wavelength (nm)

- RGB CL map quartz sandstone
  - B. G. Haile (Uni. Oslo)
  - 50 μm

- Hyperspectral CL map shocked quartz
  - M. Hamers (Uni. Utrecht)
  - 2 μm

- Hyperspectral map zircon
  - Spectra zircon
  - Normalized CL intensity
  - Wavelength (nm)

- Hyperspectral map shocked quartz
  - 2 μm
Floor-model SEM CL

+ High data quality
+ High spatial resolution
+ Modular and flexible
+ Correlation with other advanced SEM techniques

- High price
- Dedicated lab space and complex infrastructure needed
- Large footprint
- Expert user

**Question:** How do we make CL imaging more accessible and simpler?
Table-top CL

Table-top scanning electron microscopes are compact, user friendly, and affordable. Currently, there are no proper CL solutions for such systems, however. Here, we integrate a CL system on a table-top SEM.

+ Low price
+ Simple to use
+ Fast
+ Small footprint
+ Little infrastructure required

- Lower spatial resolution
- Smaller range of acceleration voltages
System approaches

**Fiber based collection system**

- Simple collection system with fiber and GRIN lens
- Direct coupling into spectrometer
- Relatively low collection efficiency due to reduced NA

**Mirror based collection system**

- Higher collection efficiency
- Design is finished
- Results coming soon!
First results with fiber based CL system

- Hyperspectral CL maps for zircons with a full spectrum in every scanning pixel
- BSE and CL image show inverted contrast which is common in zircons
- Emission from Lanthanide ions is visible in the spectrum

More results are coming, stay tuned!

Settings: 15 kV, 500 ms dwell time
If you have any questions about cathodoluminescence imaging in general or about table-top cathodoluminescence feel free to contact me at coenen@delmic.com or visit our website www.delmic.com

More CL imaging at the EGU:
Please visit this presentation if you are interested!
EGU2020-20478  Session BG4.4
"Correlative cathodoluminescence and EDS imaging of the benthic agglutinated foraminifer Liebusella goesi"
Sangeetha Hari et al., Wednesday, 06 May 2020, 08:30-10:15
Supplementary slides
Cathodoluminescence is the process whereby light (UV-VIS-IR) is generated when an electron beam hits a specimen. The emitted light carries a signature of the electronic structure of the material.
Cathodoluminescence process in rocks

For a crystalline material, electrons in that material can only occupy certain energy states. Typically, (almost) all electrons reside in the valence band.

- Rocks are typically insulators with wide band gaps between 5 - 15 eV (DUV-EUV)
- In CL we measure in the 0.8 – 6 eV range
- Defect states play an important role
Defect emission in rocks

There are many types of defects in rocks some of which have a distinct CL signature.

- **Intrinsic**
  - Vacancies
  - Interstitials
  - Dislocations
  - Growth
  - Damage

- **Extrinsic**
  - Foreign dopants
  - Rare earths (Eur, Yb, Nd)
  - Transition metals (Mn, Fe, Cr, Ti)
  - Sensitizers
  - Quenchers

**Diagram**

- Band gap
  - Valence Band
  - Conduction Band
  - Defect states

**Defects**
CL versus other SEM-based techniques

- **SE detection:**
  - Surface topography
  - (Minor) Material contrast

- **BSE detection:**
  - Density/atomic number
  - Material contrast

- **EBSD:**
  - Crystal structure
  - Crystal orientation

- **WDS/EDS detection:**
  - Core transitions
  - Quantitative composition

- **Cathodoluminescence:**
  - Composition
  - Crystal structure
  - Trace elements/dopants
  - Crystal defects
  - Ionization state

CL can be used to extract various types of information and gives a unique contrast.
Sample preparation for SEM-CL

Rock sample

- Thin section
- Plug

Surface quality
- Polishing
- Coating with metal or carbon
- High-pressure SEM

Surface conductivity
CL imaging modes

CL intensity mapping

- Measure CL intensity
- Short dwell times (10 - 100 µs) → video-rate imaging
- Coarse spectral filtering and RGB mapping

CL spectroscopy

- Measure CL spectrum
- Longer dwell times (10 - 1000 ms)
- Hyperspectral imaging with high spectral resolution