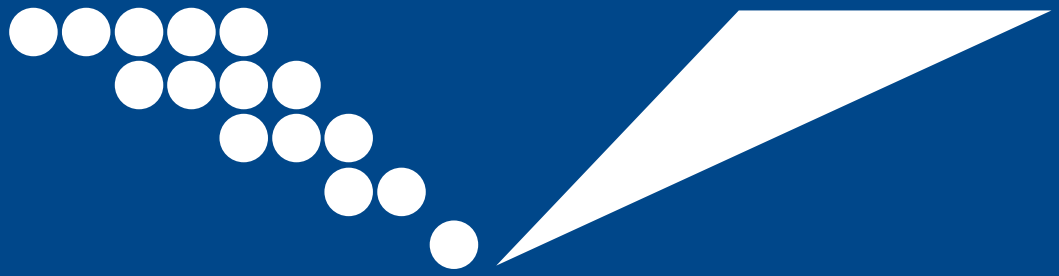
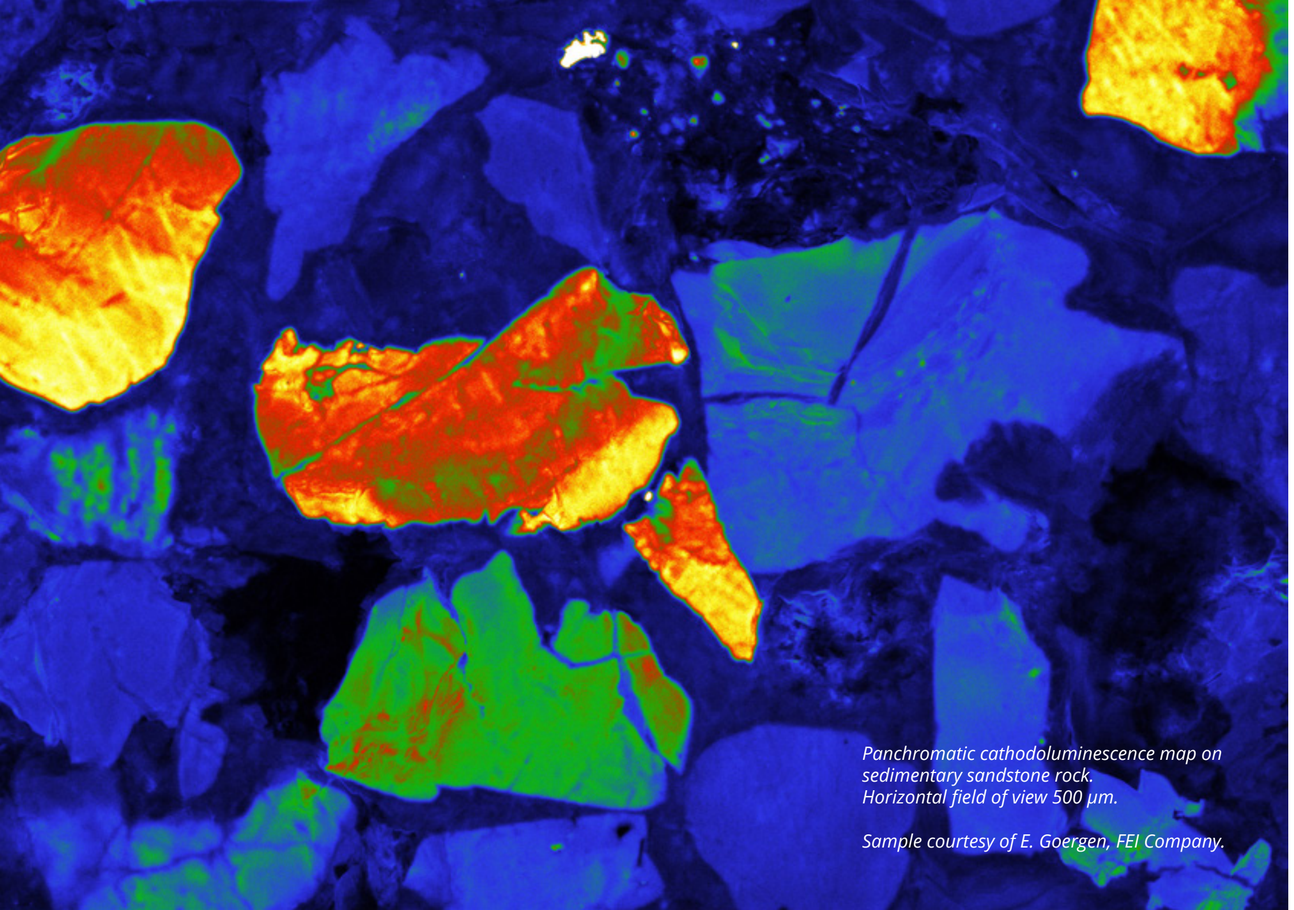


SPARC



Panchromatic cathodoluminescence map on sedimentary sandstone rock. Horizontal field of view 500 µm.

Sample courtesy of E. Goergen, FEI Company.

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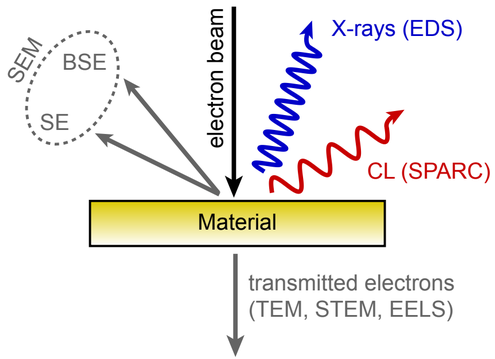
Cathodoluminiscence

When an electron beam interacts with a material, the radiation that is generated in the ultraviolet/visible/near-infrared regime of the electromagnetic spectrum is referred to as cathodoluminescence (CL).

As the increase use of optoelectronic devices and materials nowadays, the control of light at the nanoscale becomes more and more important. CL can be used to study light transport, scattering, electronic structure of a material (e.g. bandgap, defects), resonant phenomena and much more. It thus presents a valuable source of information for fundamental research as well as applied research with a direct link to industry (metrology, failure analysis).

Currently, DELMIC offers three high-performance CL detectors: SPARC Spectral, SPARC Compact, and JOLT.



SPARC

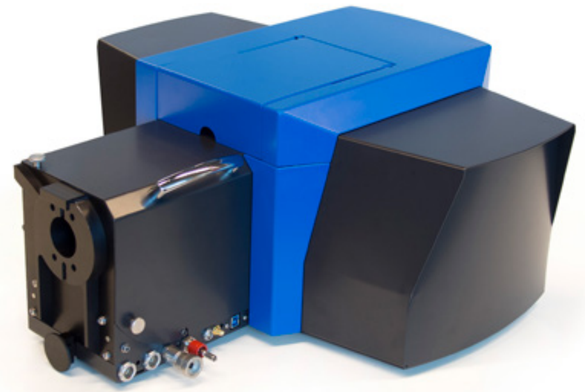
High-performance CL detectors

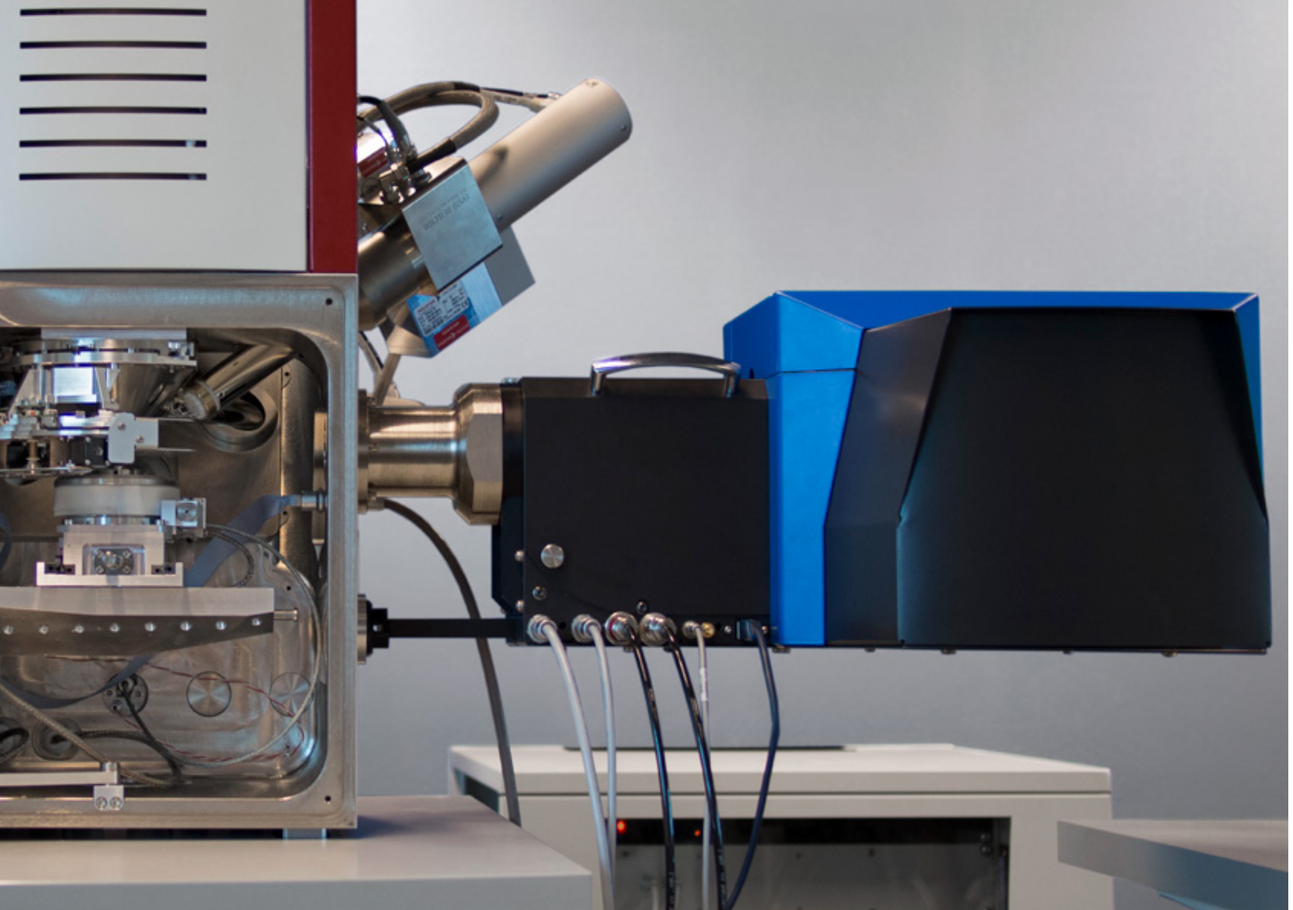
The SPARC is a CL detector which offers ultimate resolution, reliability, as well as excellent user experiences.

A large, ultraflat parabolic mirror is mounted on a high precision stage. All optics are free-space coupled, ensuring maximum photon yield. The system is modular and open, allowing for the addition of multiple optical components and a wide range of detectors. The open source software-written in phantom makes it possible to easily add functionality.

Both the hardware and the software of SPARC system are closely integrated with the scanning electron microscope (SEM). The mounting of the hardware is done on a vacuum port, which is minimally invasive for the SEM. It only takes less than five minutes to bring the SEM from CL mode back to its full original configuration.

The SPARC is being used worldwide for research in optics, materials science, and geology.





The SPARC platform
at a glance

+ High performance cathodoluminescence detection system

+ Various imaging modes

+ Modular design gives you full experimental freedom

+ High precision, automated mirror alignment stage ensures unprecedented photon yield and reliability

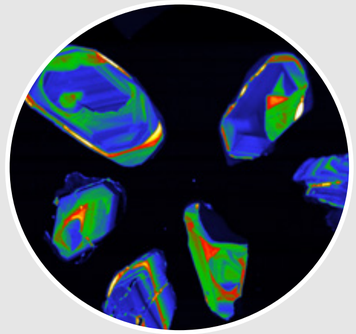
+ Open-source software improves your imaging workflow

+ Get spectroscopic information at the nanoscale, down to the resolution of a SEM

Key features

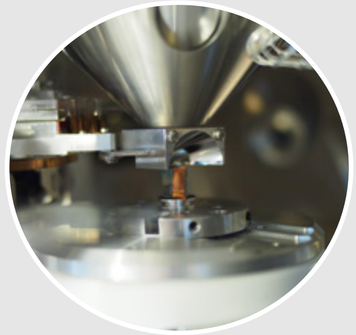
Unsurpassed sensitivity

The paraboloid mirror is made of a unique type of aluminium. The tiny size of the aluminium ensures maximum flatness of the mirror, enhancing the photon yield, decreasing measurement time and reducing artifacts. The unique and precise automated alignment procedure provides unrivalled user-friendliness.



Motorized mirror stage

In order to ensure the best performance and enable reproducible alignment between experiments, the mirror has been mounted on a motorized high-precision stage. This allows you to quantitatively compare different measurements.



Modular design

The modular nature of SPARC offers you full experimental freedom, and guarantees a future proof setup. Optical boxes can be easily replaced, which enables you to extend and add features to the system as your research needs evolve.

User-friendly

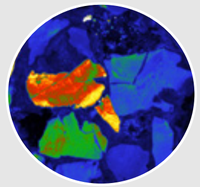
ODEMIS is an open-source software package used for all Delmic microscopes. This software is straightforward to use. It can control the electron beam to allow for data acquisition and analysis. The modular design of SPARC in combination with ODEMIS ensures a user-friendly solution which is a truly unique and ultimately versatile research instrument.

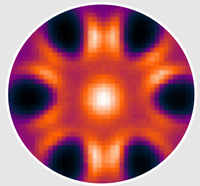
Imaging modes

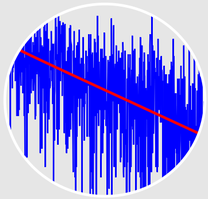
Fast–intensity mapping
Fast-intensity mapping allows you to do easy rapid inspection of large areas, fast device inspection, and efficient region-of-interest finding. A filter wheel can be used for spectral differentiation.

Angle–resolved CL spectroscopy
The SPARC is the first CL detector which provides the option to acquire angle-resolved images. Rather than focusing the light signal on a fiber or narrow opening, an image of the mirror can be projected onto an imaging camera. This allows for the detection of the directionality of the emitted light, also known as momentum spectroscopy. In this mode, a filter wheel is used to spectrally distinguish the different emission wavelengths.

Hyperspectral imaging
When the SPARC system is used in spectral mode, the light coming from the mirror is focused on a slit or fiber connected to a Czerny-Turner spectrograph. A variety of imaging detectors can be used to cover a spectral range of 200-1600 nm. By scanning the e-beam across the sample, a spatially resolved hyperspectral image is produced.





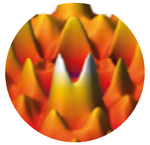


CL polarimetry
Using a polarizer or even a full polarimeter in the angle-resolved mode allows for the reconstruction of the polarization state (Stokes vector) of CL for different emission angles. An advanced correction for the optical system including the paraboloid mirror is required for this reconstruction. This is provided with the polarization system.

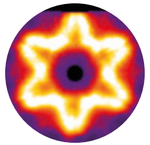
Time-resolved CL imaging
With the latest and unique technology from Delmic, it is now possible to perform g(2) and lifetime imaging and observe the time dynamics of various nanomaterials. Time-resolved imaging is highly relevant for a wide range of applications, including semiconductors for photovoltaics and light-emitting devices, as well as single emitters for quantum information processing and sensing.

Application areas

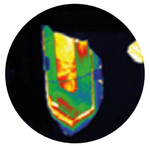
The SPARC opens up new avenues of research such as electron beam induced nanophotonics, but its sensitivity and ease of use also make it possible to breathe life into more 'traditional' applications of cathodoluminescence



The SPARC offers users advanced understanding of semiconductor and optoelectronic devices. The high collection efficiency even allows the investigation of poor emitters of light, such as silicon-based materials.



Cathodoluminescence gives an additional contrast mechanism for materials inspection, failure analysis, geology, and petrology applications. CL imaging is an ideal tool, because it is fast and it provides information, not easily available by other techniques.



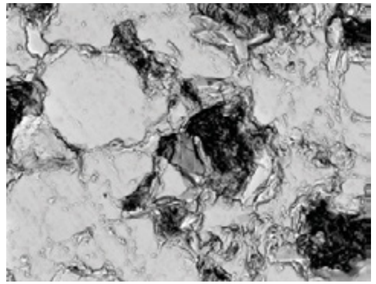
For both the pharmaceutical as well as the life sciences industry, CL can be used to screen active pharmaceutical ingredients and offers spectral fingerprinting.

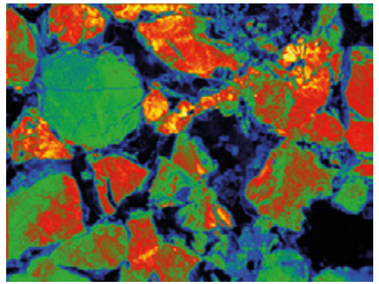
Example

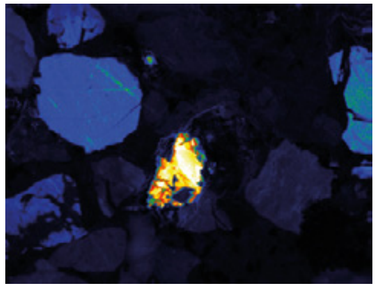
Geology

Cathodoluminescence imaging is particularly useful for providing mineralogical information. The color and intensity of the emitted light gives insight into processes as crystal growth, replacement, deformation, provenance, and defect structures and can be used to fingerprint minerals down to the resolution of a scanning electron microscope.

The SPARC is an ideal solution for researchers in geology since it can be retrofitted to any scanning electron system (SEM) to produce high-performance cathodoluminescence images.







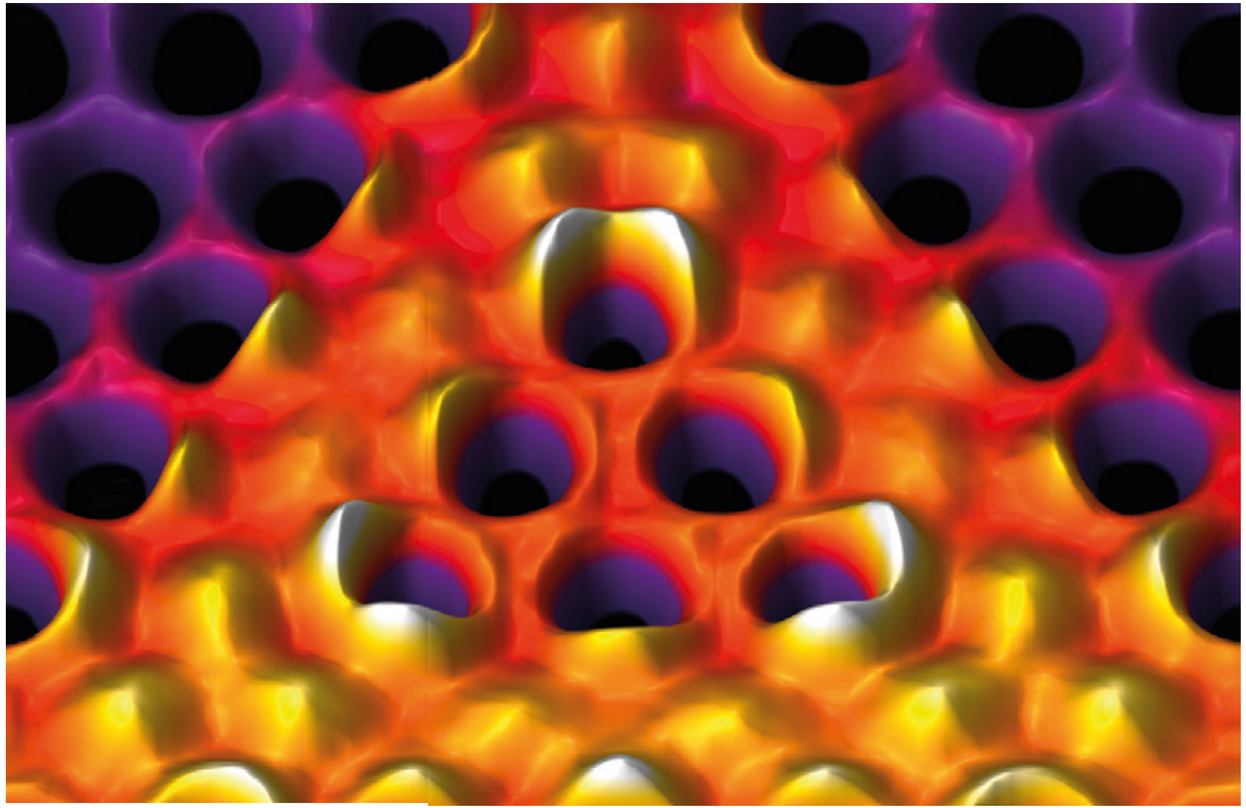
Example

Nanophotonics

The SPARC offers a very powerful method to study optical phenomena at the nanoscale and to understand how light couples to matter in a fundamental way. It is also a useful tool for improving the performance of optoelectronic devices, because the light-emission maps created with the technique reflect the local density of electromagnetic states, a quantity that detemines how well light couples to matter and vice versa[1].

The SPARC enables the study of nanostructures with deep-subwavelength resolution. The electron beam is used to excite nanostructures and the cathodoluminescence detector is subsequently used to detect the generated light. The higher detection efficiency not only leads to better results, but also makes it possible to do a whole new type of nanophotonics research; angle resolved measurements. With this new detection method, the direction in which the light is emitted from an excited structure can be mapped as a function of the excitation position.

[1] *Electron beams set nanostructures aglow, Nature 493, 143 (10 January 2013) doi:10.1038/493143a*



Cathodoluminescence excitation map showing an optical cavity mode of a triangular defect cavity in a 2D silicon nitride photonic crystal membrane.

(R. Sapienza et al., Nat. Mater. 11, 781 (2012))

Image courtesy of T. Coenen, FOM institute AMOLF

Specifications

SPARC Spectral

+ Panchromatic and monochromatic imaging with high spatial and spectral resolution

+ Spectral response can reach 185 – 2000 nm

+ Ultraflat parabolic mirror, enhancing reflectivity, decreasing measurement time and reducing artifacts

+ 87% collection efficiency from a Lambertian source

+ Automated control and alignment of mirror stage

+ Advanced open-source software for data acquisition and in-depth analysis

+ Various imaging mode

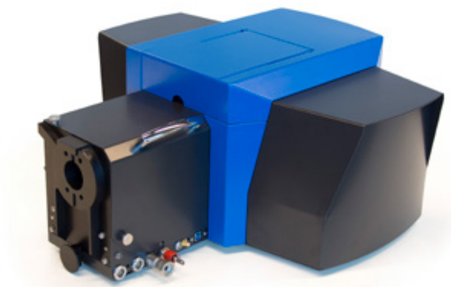
+ Fast–intensity mapping

+ Angle–resolved CL spectroscopy

+ Hyperspectral imaging

+ CL polarimetry

+ Time-resolved CL imaging



SPARC Compact

A small-scale version of the SPARC Spectral

+ Panchromatic imaging with high spatial resolution

+ Spectral response: 400-700 nm (Optional: 185 – 870 nm)

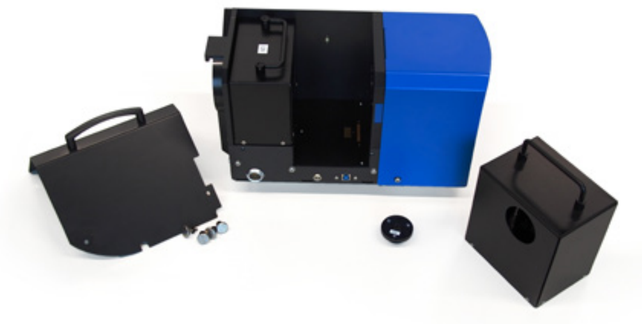
+ Spectral differentiation and RGB color imaging

+ Ultra-smooth, parabolic mirror, enhancing reflectivity, decreasing measurement time and reducing artifacts

+ 87% collection efficiency from a Lambertian source

+ Automated control and alignment of mirror stage

+ Advanced open-source software for data acquisition and in-depth analysis



JOLT
The newest member of SPARC CL detection product family

+ Panchromatic CL detection (RGB option is available)

+ Easy to install by mounting on single port, no need for alignment

+ Spectral range: 270 – 900 nm

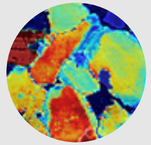
+ User friendly operation

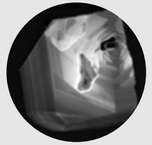
+ Works in combination with other detectors

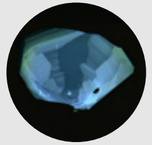
+ External control panel for image optimization and signal controls

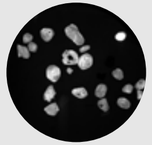
+ Based on unique high-end MPPC sensor technology

+ Compatible with all SEM models









ODEMIS
Integrated software

ODEMIS allows for easy acquisition and analysis of the data. The software controls the scanning of the electron beam acquiring both secondary electron images and the triggering for the acquisition of spectral and angular resolved images. Spectral response data can immediately be subtracted from the datasets, showing the 'clean' spectrum at a glance. ODEMIS is open-source and makes use of the open file formats OME-TIFF and HDF5.

In particular, the software has the following features for acquisitions:
+ DRIFT CORRECTION

+ SIMULTANEOUS ACQUISITION of the secondary electron and spectral or angle-resolved images

+ Easily obtain images over an ARBITRARILY SIZED GRID with an arbitrary number of pixels

+ Easily obtain a large number of ANGLE-RESOLVED images

In analysis
+ Easily visualize 3D CL data as a 2D MAP or pixel by pixel graph

+ I mmediate POLAR PLOTTING of angleresolved images

+ Use CORRECTION FILES (such as the system response function) to obtain a corrected spectrum in one go

+ For detailed analysis easily transfer files to for example MATLAB

+ Advanced 2D slicer through 3D dataset with adjustable integration limits

+ Overlay of SEM and spectral images

Kanaalweg 4
2628 EB Delft
The Netherlands
Tel: +31 1574 40158
info@delmic.com
www.delmic.com