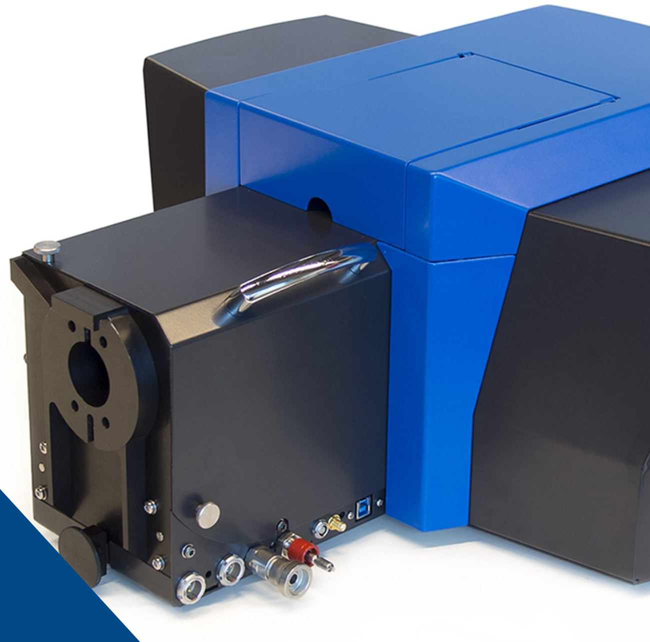

S P A R C

technical note

Hyperspectral Cathodoluminescence Imaging

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SPARC

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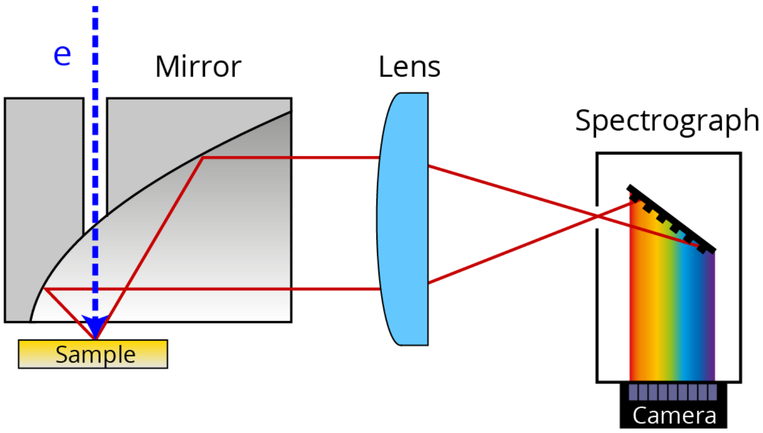

Figure 1 *Schematic representation of the hyperspectral imaging mode.*

An electron beam is inherently a broadband (white) excitation source. The resulting cathodoluminescence (CL) emission can therefore be composed of light with many different wavelengths (colors). Which wavelengths are dominant depends on the local material composition, configuration, and geometry. In panchromatic imaging, one measures the total intensity of all the wavelengths combined. However, much information is lost in this way as the wavelength distribution (spectrum) often contains valuable information on the local optical and structural properties of the material.*

Wavelength information can be obtained by using color filters, but this can be tedious as a scan has to be performed for each wavelength. In hyperspectral imaging a complete spectrum is collected in a parallel manner providing a high-resolution spectrum for every electron beam position. The CL emission is directed towards a Czerny-Turner spectrograph containing a diffraction grating and a pixelated CCD, CMOS, or photodiode array. The diffraction grating spatially disperses the different emission wavelengths over the camera such that each line of pixels corresponds to a unique wavelength. This is illustrated in figure 1. The coupling into the spectrograph can either be through free space (shown here) or through an optical fiber (not shown). Efficient hyperspectral imaging requires a perfect parallel beam from the probation which can only be obtained when the mirror is properly aligned. The SPARC system excels at this as it has an advanced micro-positioning system.

* See SPARC application notes.

Hyperspectral imaging yields a 3D datacube in which two of the dimensions represent the spatial electron beam position (x,y) and the third represents the wavelength. This datacube is similar to what is collected in EDS or WDS but for UV/VIS/IR wavelengths rather than x-ray wavelengths. The CL datacube contains a wealth of information which can be visualized in many different ways. For example, the spectrum corresponding to a specific excitation position can be depicted as is schematically shown in 2(b). Figure 2(c) shows two such spectra collected on a quartz sample at different excitation positions. Both show characteristic quartz CL peaks but the blue peak is clearly absent in spectrum 1. If required, spatial averaging can be used to improve the signal-to-noise ratio in the spectra.

Rather than showing the spectrum for a specific point it is also possible to rigorously visualize spatial differences in the emission for every excitation position. For example, a (false) color RGB image can be extracted from the datacube where the emission spectrum is divided in three RGB channels in a certain spectral range. In this case we chose the spectral region from 380 to 700 nm which covers both peaks as is shown in 2(c). Figure 2(e) represents the corresponding spatial false color map. Consistent with 2(c), region 1 is red as the peak at 650 nm is dominant whereas region 2 is purple as both peaks are present which puts significant intensity in both the red and the blue color channel.

An alternative method of visualizing the datacube is by taking a slice through the datacube at a specific wavelength yielding a wavelength filtered grayscale image (schematically shown in 2(b)). Figures 2(f) and (g) are examples of such images for the same area which clearly show that the blue peak is absent in the central region 1. Averaging over a larger bandwidth can be used to reduce noise in the image. These examples illustrate the power and diversity of hyperspectral imaging.

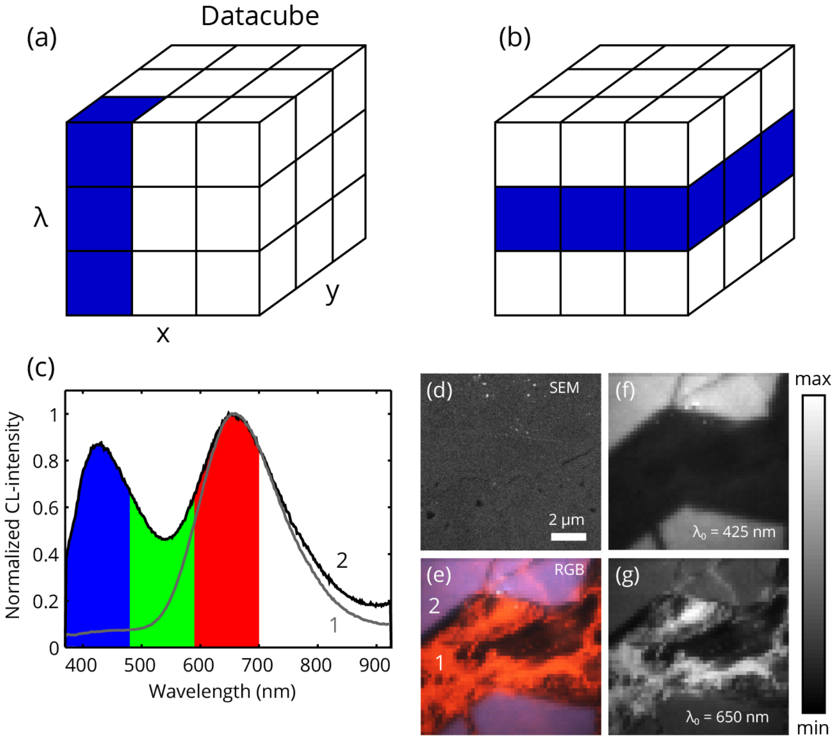

Figure 2 *(a) Hyperspectral CL datacube containing the 2D spatial electron beam position and the emission wavelength λ. For each point a full spectrum is collected. (b) From a datacube, it also possible to extract the spatial distribution for a specific wavelength. (c) CL spectra measured on quartz sandstone. (d) SEM image of a region on a quartz sandstone. (e) False color RGB image taken from λ = 380-700 nm as indicated in (c). The positions from which spectra 1 and 2 are collected are also indicated. Wavelength cross cuts through the datacube (shown schematically in (b)) at (f) 425 and (g) 650 nm corresponding to the two main peaks in the quartz.*

DELMIC B.V. is a company based in Delft, the Netherlands that produces correlative light and electron microscopy solutions. DELMIC's systems cater to a broad range of researchers in fields ranging from nanophotonics to cell biology.

The SPARC is a high-performance cathodoluminescence detection system produced by DELMIC. The system is designed to optimally collect and detect cathodoluminescence emission, enabling fast and sensitive material characterization at the nanoscale.

For questions regarding this note, contact our SPARC Application Specialist at: coenen@delmic.com

For more SPARC technical notes, see: delmic.com/sparc/technical_notes.php

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