MESA+ INSTITUTE FOR NANOTECHNOLOGY

NanoLab Twente

SEM EXAMPLE

CATHODOLUMINESCENCE IN SEM

Announcing the latest acquisition of the Nanolab Analysis Section:

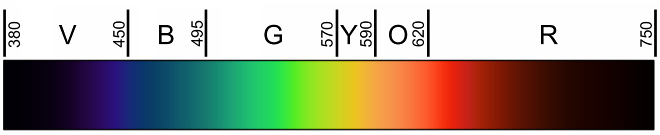
the Gatan MonoCL4 CATHODOLUMINESCENCE

detector or, in short, the CL detector.

A CL detection system has been placed onto the ZEISS HR-SEM in the Nanolab. A CL detector produces high resolution digital CL images from luminescent materials.

CL is the emission of photons of a characteristic wavelength, λ, from a sample after bombardment with an electron beam. It occurs because the impingement of a high energy electron beam onto a semiconductor results in the promotion of electrons from the valence band into the conduction band, leaving behind a hole. When an electron and a hole recombine a photon may be emitted depending on the material, especially upon its' purity, its' defect state and of course, which material it is. In this case, the semiconductor can be almost any non-metallic material. In terms of band structure semi-conductors, insulators, ceramics, minerals, and glasses can be all treated in the same way.

In an SEM a material is scanned with a finely focussed beam of electrons. The interaction with the sample surface produces a number of signals including secondary and back-scattered electrons, x-rays, and of course, photons which are used by the CL detector. The light emitted is collected by an optical mirror and transferred via an optical fibre into a monochromator and then detected by a photomultiplier tube.



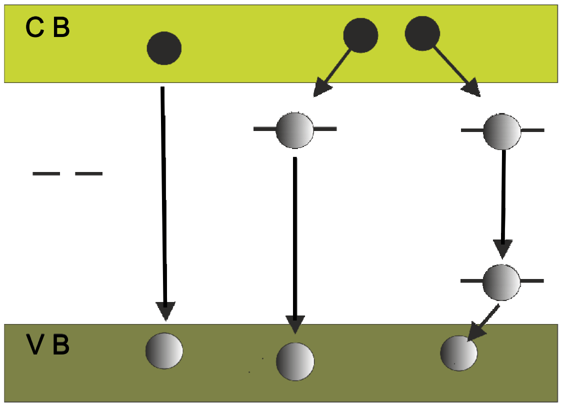


Figure 1. Illustration of the possibilities for CL emission in an insulator dependent on the path the electron has taken, and if and when it has encountered an intrinsic and/or extrinsic trap.

CB: Conductance band

VB: Valence band

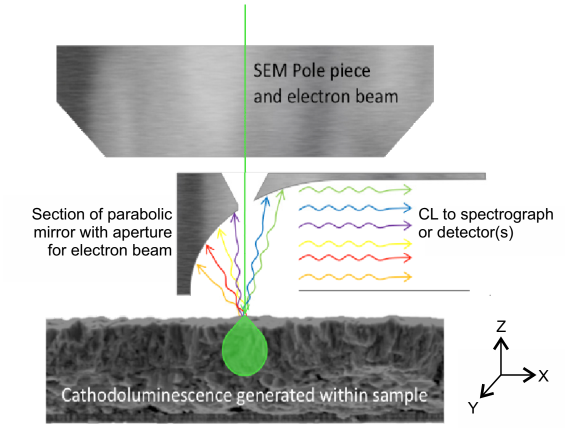


Figure 2. Illustration showing the depth of penetration, path of the CL photons to the CL mirror and towards the light pipe.

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Figure 3. Illustration showing the complete path of the electrons in the SEM to the imaging of the CL and SE signals on the SEM monitor

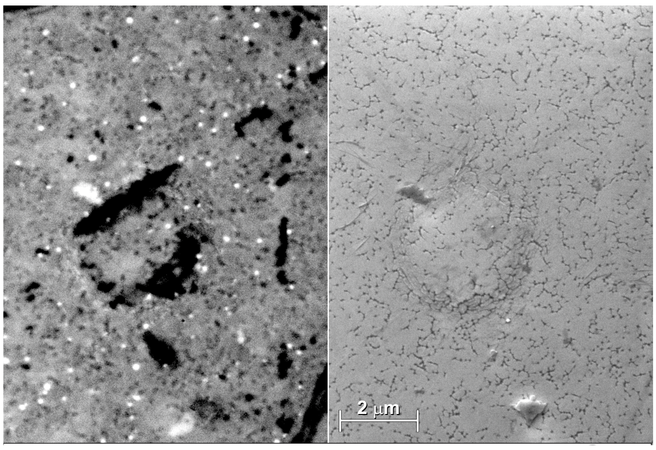

Figure 4. Characterisation of an annealed GaN layer on a sapphire substrate, showing its surface morphology by SE imaging (r), and the location of luminescent sites by CL (l).

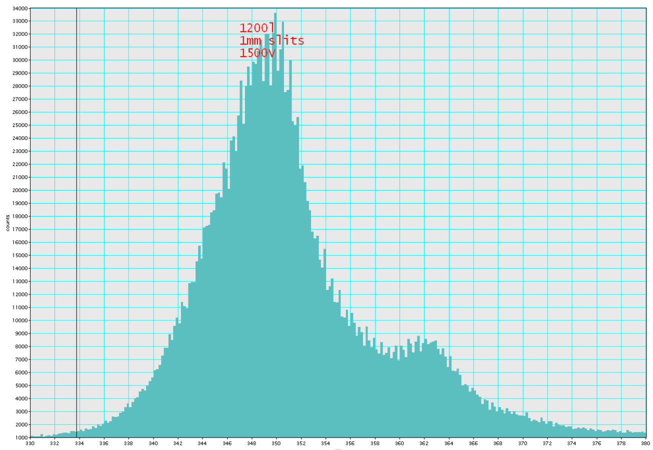

Figure 5. Spectrum of wavelength of emitted photons from an MOCVD thin film of GaN on a sapphire substrate.

Application:

Cathodoluminescence is a technique that can be used in a number of important fields in nanotechnology. The most well known is the semiconductor technology where CL is used for:

- device failure analysis
- quantum structure analysis
- and for imaging defects of all sorts.

Other fields include:

- geology
- mineralogy
- photonic crystals
- surface plasmons in metallic nanoparticles
- the identification of organic groups in drugs research for the pharmaceutical industry.

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