

Not just secondary electrons!

A new low-vacuum hybrid secondary electron detector that also detects light emission information (CL)

Product used : Scanning electron microscope (SEM)

Introduction

The low vacuum hybrid secondary electron detectors are now able to form secondary electron image from light signals, greatly improving the live image quality of the low vacuum secondary electron image. In addition, by switching modes, an image coming from a light emission signal (cathodoluminescence :CL) of a specimen due to electron-beam irradiation can be obtained. Accordingly, contrasts from crystal defects and impurities of very small quantity can be obtained, enabling observation and analysis that were not possible before.

Low vacuum hybrid secondary electron detector (LHSED)

The low vacuum hybrid secondary electron detectors are now able to acquire light signals as well as electron signals.

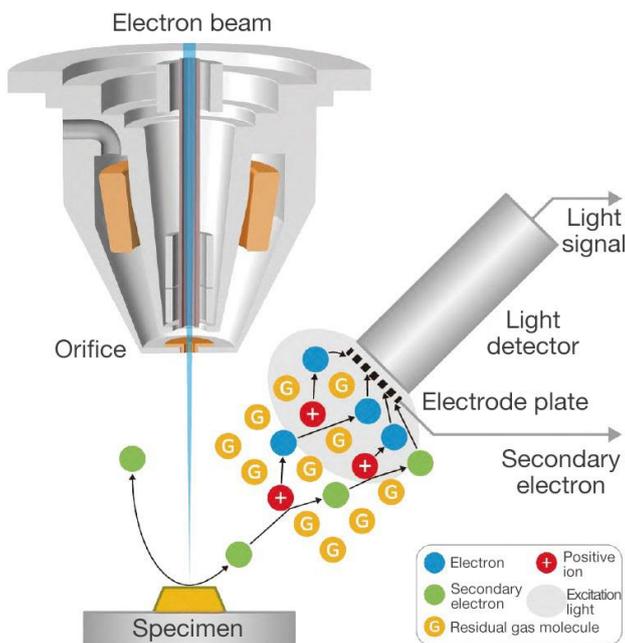


Fig. 1 Principle of LHSED signal acquisition

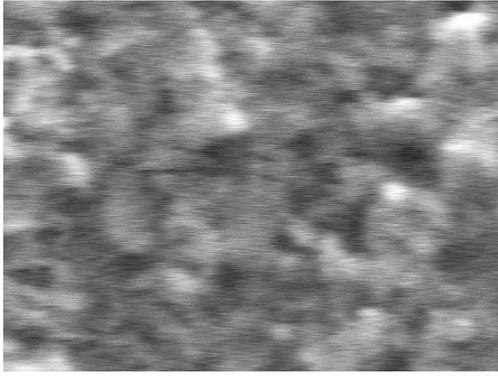
Table 1 LHSED three modes

Mode	LSED-E	LSED-P	PD
Vacuum mode	Low vacuum	Low vacuum	Low/ High vacuum
Electrode plate	Application of voltage	Application of voltage	Without application of voltage
Signal	Secondary electron	Light (Excitation from secondary electron)	Light (Direct excitation from a specimen)
Information	Topographic information	Mainly topographic information (light emission information included, slightly though)	Light emission information
Details	Acquire secondary electrons generated by the collision of electrons emitted from the specimen with gas molecules	Acquire light generated by collisions between secondary electrons from the sample and gas molecules	Acquire light directly excited from a specimen by irradiation of primary electron beams

●Live image quality of low vacuum secondary electron greatly improved

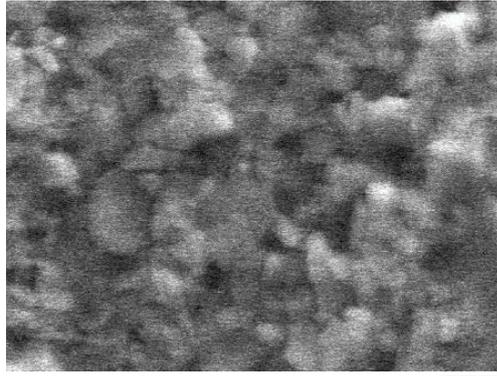
Acquiring excitation light has improved live image quality, making ease of operation better.

Conventional low vacuum secondary electron detector



500 nm

Low vacuum hybrid secondary electron detector (LSED-P)



500 nm

Fig. 2 Low vacuum secondary electron image of business card. Accelerating voltage 5 kV, magnification x 30,000, scan time 0.15 seconds

Acquisition of light emission information by LHSED(PD mode)

When a specimen is irradiated by electron beams, various signals are generated. Electrons in a solid are excited by electron-beam irradiation leaving holes. The electrons recombine with the holes to emit light, which is called "Cathodoluminescence". By acquiring the signals, structures of crystal defects and others in materials can be examined, which can be applied to the analysis of semiconductors and minerals.

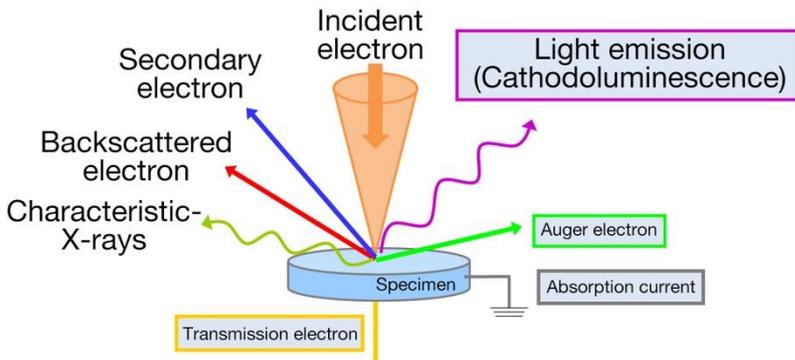


Fig. 3 Various signals generating during electron beam irradiation

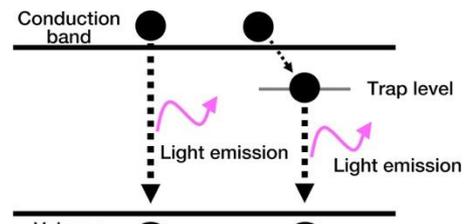
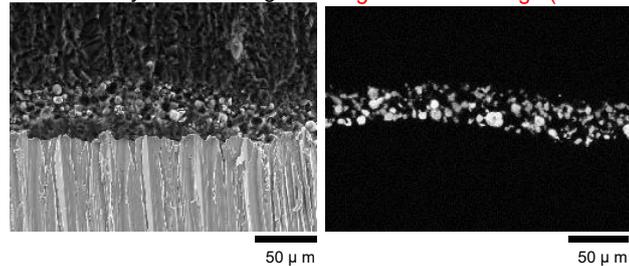


Fig 4 Schematic diagram of CL light emission
CL is generated as extra energy when an electron excited in conduction band or an electron in trap level recombines with a hole in valence band.

(a) Secondary electron image and Light emission image with SEM

Secondary electron image Light emission image (LHSE PD)



Contrast of LHSE PD obtained by photographing LEDs was verified by CL detector and found to detect light in the wavelength range around 450-700 nm

(b) Cross-check result using CL detector*

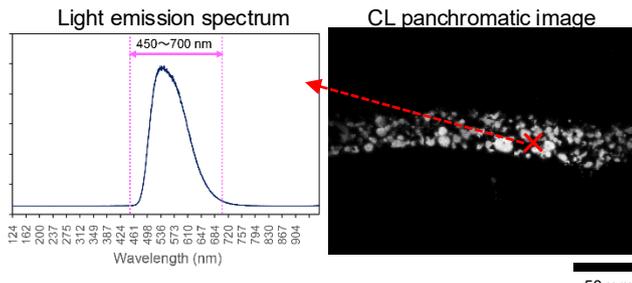


Fig.6 Comparison of light emission information from LED fracture surface between LHSED and CL detector

*CL detector used : CL detector F-CLUE by Horiba Ltd.

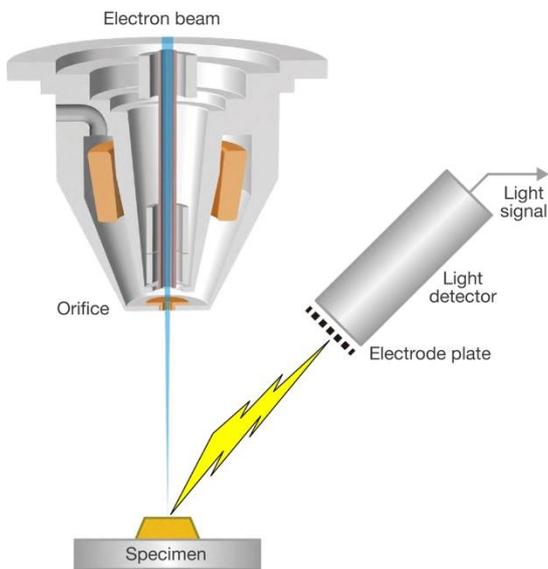


Fig.5 Schematic diagram of signal acquisition in PD mode

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Application example using LHSE PD mode

● ZnO particle in Zn particle

There are oxides that emit light by electron beam irradiation. Judging an oxide normally requires elemental mapping. However, acquiring a PD image can identify the location of oxides in a short time.

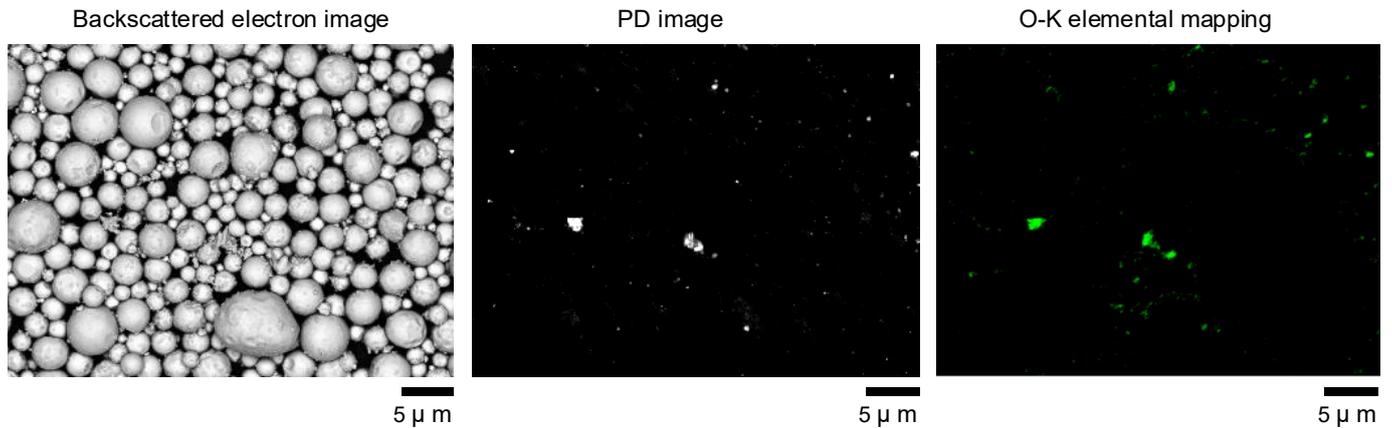


Fig. 7 SEM image and elemental mapping image of Zn particle and ZnO particle in the Zn particles
Accelerating voltage : 10 kV, Magnification: x3,000

By combining with the montage function, the distribution of oxides in a wide area can be understood, which is useful for prompt understanding of foreign material distribution.

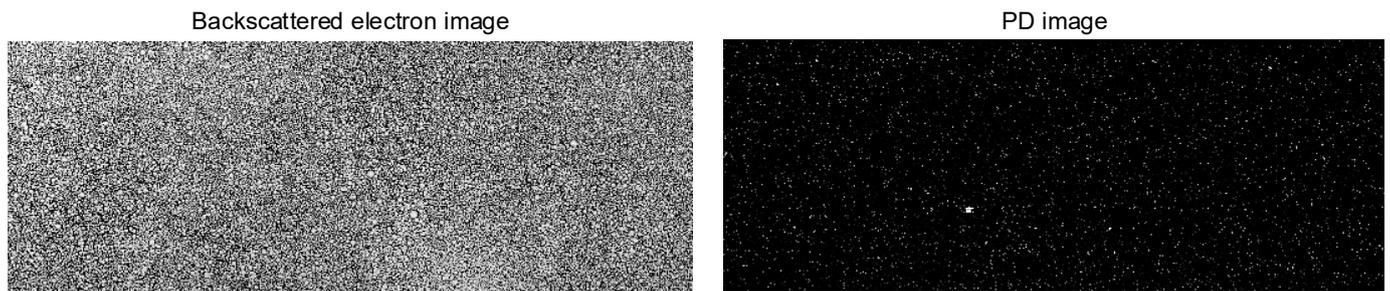


Fig. 8 Montage image of Zn particle and ZnO particle. Accelerating voltage 5 kV, Magnification of 1 field of view x 30,000, Observation range 0.852 x 0.314mm

● Observation of crystal growth striation and crystal defect of minerals

Zircon ($ZrSiO_4$)

Zircon exhibits contrasts derived from defects and impurities that occur during crystal growth. They serve as “tree rings” of the crystal and are useful for analyzing the growth stages.

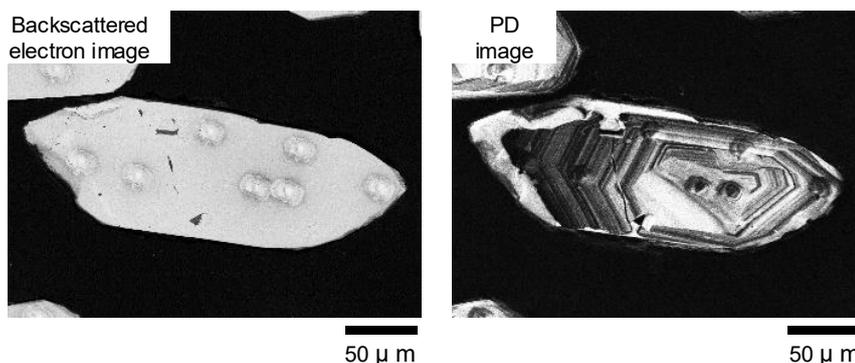


Fig. 9 SEM image of zircon. Accelerating voltage 10kV, Magnification x400

Diamond

Information derived from defects and impurities that occur during crystal growth can be obtained.

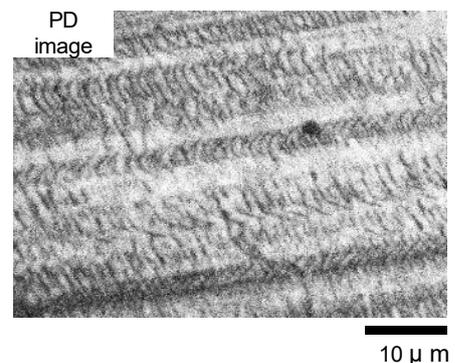


Fig.10 PD image of diamond
Accelerating voltage 5 kV, Magnification x2,500

●Dislocation observation of gallium nitride substrate

Gallium nitride(GaN) substrates which are used as power semiconductors, are an inevitable material in life today. As dislocations in the substrate can directly lead to failure of the device, the test to control them is extremely important.

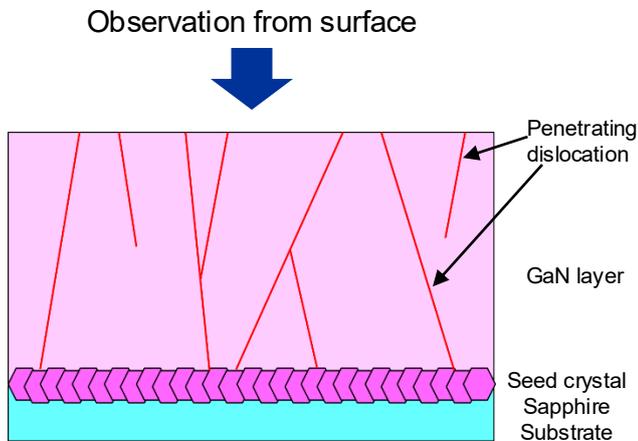


Fig. 11 Cross-sectional schematic diagram of GaN substrate

What is dislocation ?

When a slip occurs inside a crystal, the boundary of the slip is called a dislocation(line). The crystal surrounding a dislocation is highly distorted, which also affects the electrical properties of semiconductors and the corrosion resistance of metals.

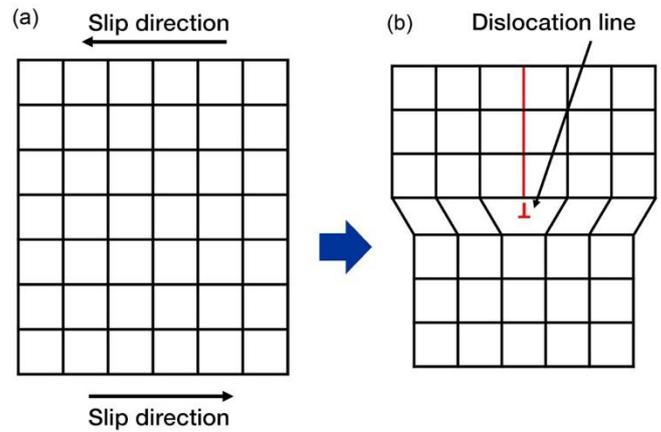
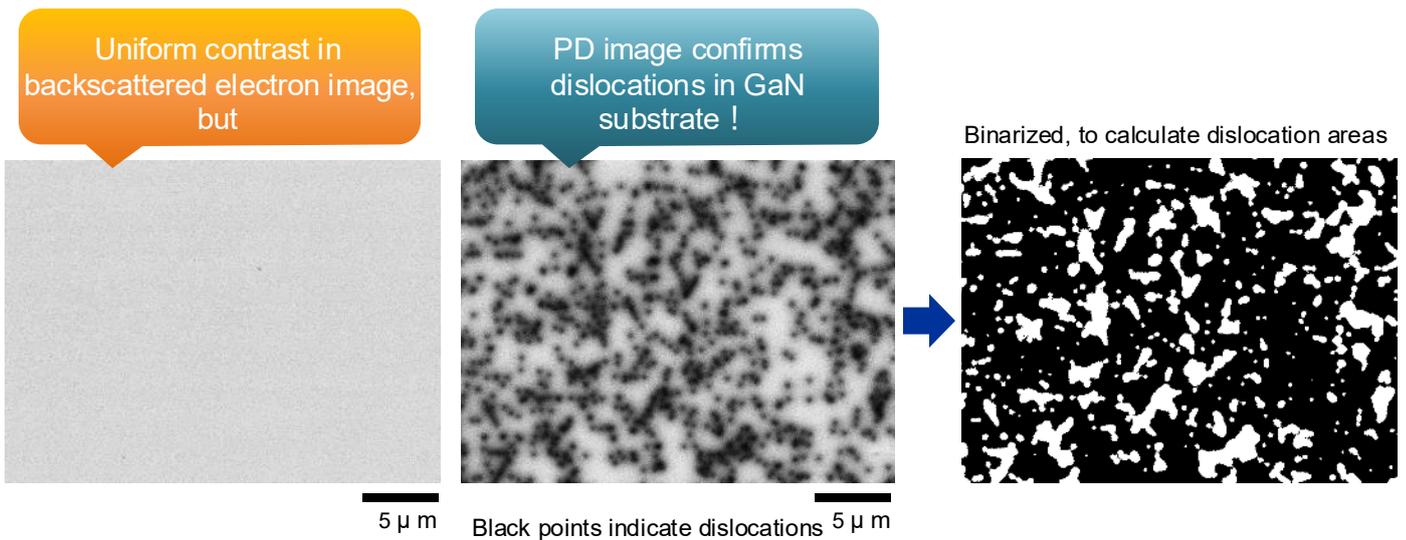


Fig. 12 (a) Slip deformation in crystal (b) Dislocation



Dislocation area : 491.52 μm^2

Percentage of dislocation against the field of view : 30.83%

Combination of PD image and image analysis software can be applied for testing of dislocation area and dislocation density in GaN.

Summary

The newly developed low-vacuum hybrid secondary electron detector (LHSED) acquires excitation light during residual gas ionization, greatly improving the live image quality of low-vacuum secondary electrons and providing better ease of use. In addition, the LHSED can acquire not only secondary electron images but also light emission images by switching the signal and can qualitatively capture light emission information instantaneously. This allows the LHSED to be used as a partial substitute for a dedicated CL detector.