Field Emission - Scanning Electron Microscopes (FE-SEM)

MERLIN®

Analytical Power for the Sub-Nanometer World

ZEISS

We make it visible.

Carl Zeiss Microscopy
Electron and Ion Beam Microscopes

More than 160 years of experience in optics has laid the foundation for pioneering light, electron and ion beam microscopes from Carl Zeiss. Superior integration of imaging and analytical capabilities provides information beyond resolution, unlocking the best kept secrets of your sample.

With a broad technology portfolio Carl Zeiss provides instruments both tailored to your requirements and adaptable to your evolving needs. With our highly versatile application solutions we endeavor to be your partner of choice.

Regional demo centers provide you with access to our applications expertise developed in collaboration with world-class partners in industry and academia. Global customer support is provided by the Carl Zeiss Group together with an extensive network of authorized dealers.

MERLIN®

Analytical Power for the Sub-Nanometer World

Nano Analytics

- High resolution & high current:
  The GEMINI® II column enables high resolution even at high probe current
- Optimized for fastest EDX, WDX , EBSD & CL signal acquisition
- Best-in-class material contrast with unique EsB® detector

Total Information

- Parallel information acquisition of compositional contrast, topographical & crystalline information through complete detection system (CDS)
- High resolution imaging of non-conductive materials through charge compensation
- Optimized image quality as a result of in-situ sample cleaning during imaging
- In-situ 3 dimensional surface modelling

Ease of Use

- Fastest Sub nm image acquisition including sample transfer in less than 60 seconds
- Professional results by novice user due to fully automated instrument adjustment
- No time consuming sample preparation of non-conductive samples due to unique charge compensation

Future Assured

- Upgradeable building blocks for decades of first class system performance
- Fastest, forward-design SEM electronics ready for future technology integration
- Upgradeable detection possibilities by plug & play solutions for years of leading edge technology integration

SEM
Scanning Electron Microscopes

FE-SEM
Field Emission - Scanning Electron Microscopes

HIM
Helium Ion Microscopes

CrossBeam®
CrossBeam® Workstations (FIB-SEM)

TEM
Transmission Electron Microscopes

Applications in Materials Analysis

MERLIN® – Analytical Power for the Sub-Nanometer World

Nano Analytics

- High resolution & high current: GEMINI® II column enables high resolution even at high probe current
- Optimized for fastest EDX, WDX , EBSD & CL signal acquisition
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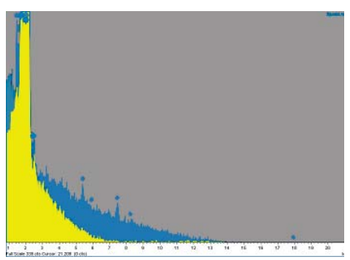
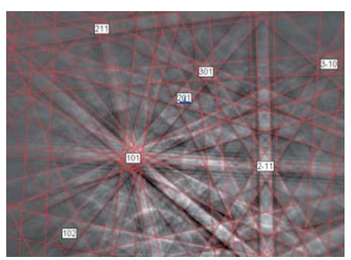
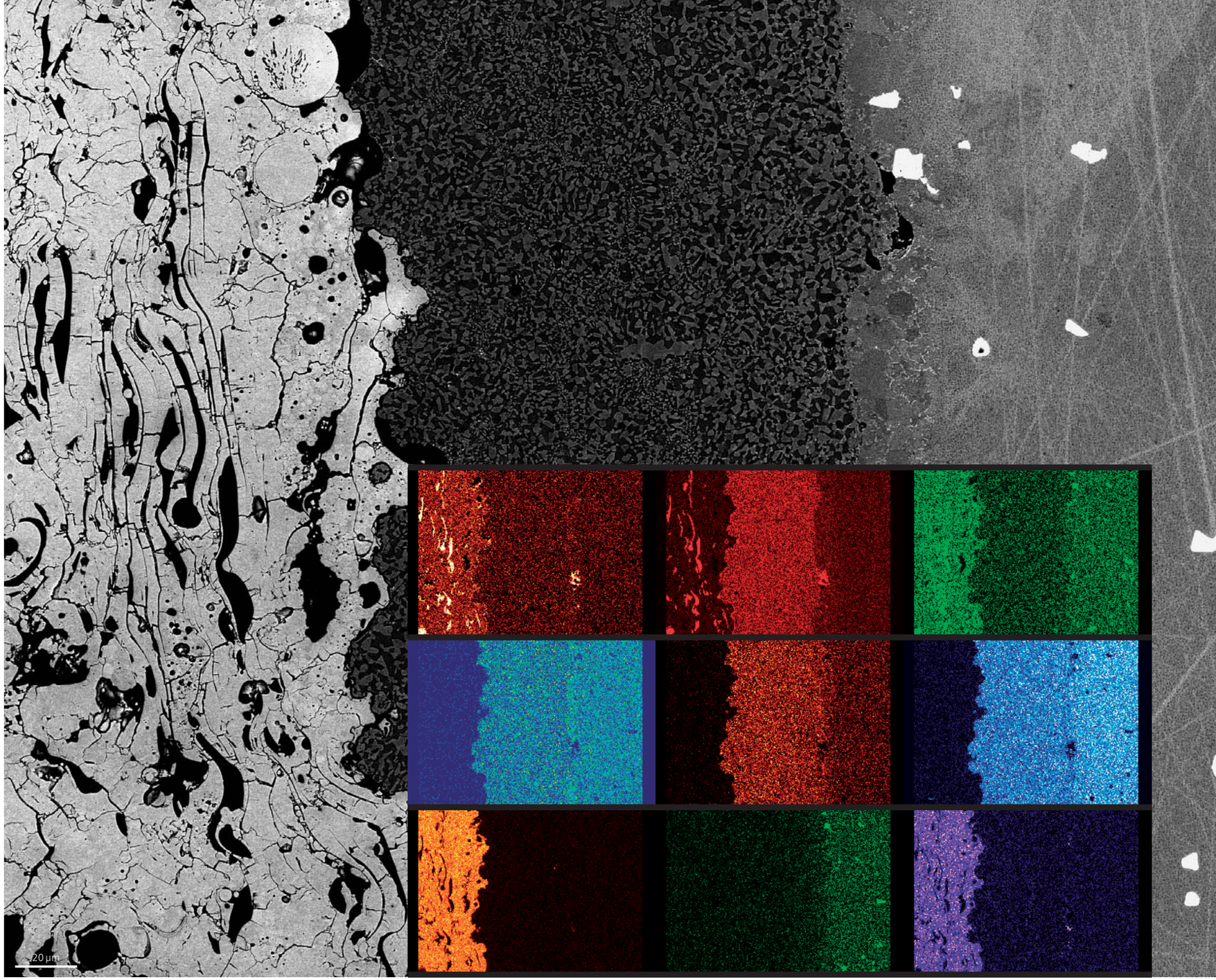


Local charge compensation produces a significant increase in the analytical data. EDS spectra of a ZrO_2 sample taken at 15 kV with (blue) and without (yellow) local charge compensation. All emission lines above approx. 6 kV are only accessible with local charge compensation.



The new MERLIN® chamber is constructed for enabling the integration of a maximum of analytical investigations methods like EDX, EBSD, WDX etc. As an example, the images show an electron backscattered diffraction image (EBSD) which can be used to elucidate texture or preferred orientation of any crystalline or polycrystalline materials.



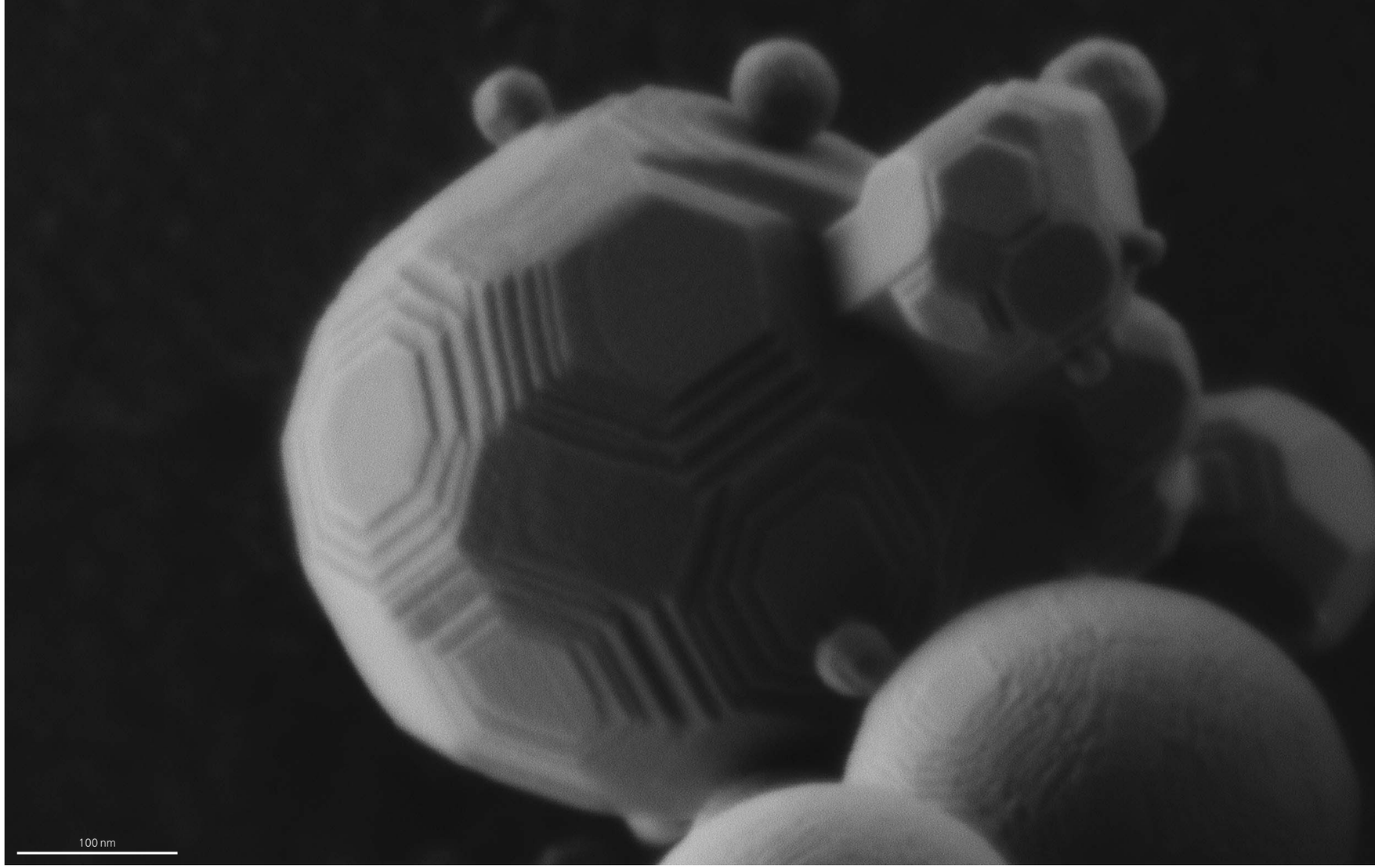
Material analysis of an airplane turbine. In-lens SE image showing different material components. Fastest EDX mappings showing detailed material contributions of different regions of the background image. Courtesy of Dr. Penkalla, Research Center Juelich, Germany.

Applications in Materials Analysis

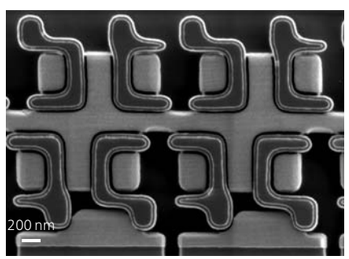
MERLIN® – Analytical Power for the Sub-Nanometer World

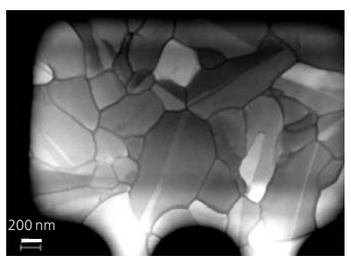
Total Information in Semiconductor Technology

- Parallel information acquisition of compositional contrast, topographical & crystalline data using the Complete Detection System (CDS)
- High resolution imaging of non-conductive materials through charge compensation
- Optimized image quality as a result of in-situ sample cleaning during imaging
- In-situ 3 dimensional surface modeling for metrology investigations

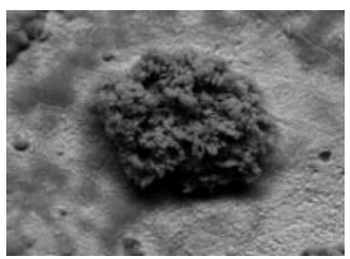


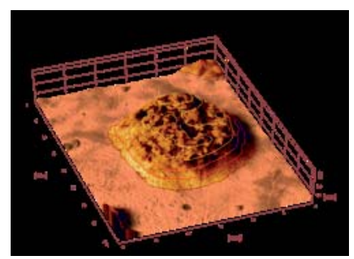
High-resolution, low kV, in-lens SE image of an aluminum-oxide (Al_2O_3) sphere. This example shows the incredible possibilities of the MERLIN® system for high-resolution examinations under extremely low kV conditions (< 500 V) as is typical of semiconductor examinations.





The integrated complete detection system within MERLIN® is the optimized solution for imaging of semiconductor samples.
The images show the topographical information of a silicon device imaged with the in-lens SE detector (left), the crystalline structure of a silicon device imaged with the AsB® detector (middle) and the material contrast information of a tungsten plug analyzed with the in-lens EsB® detector (right).





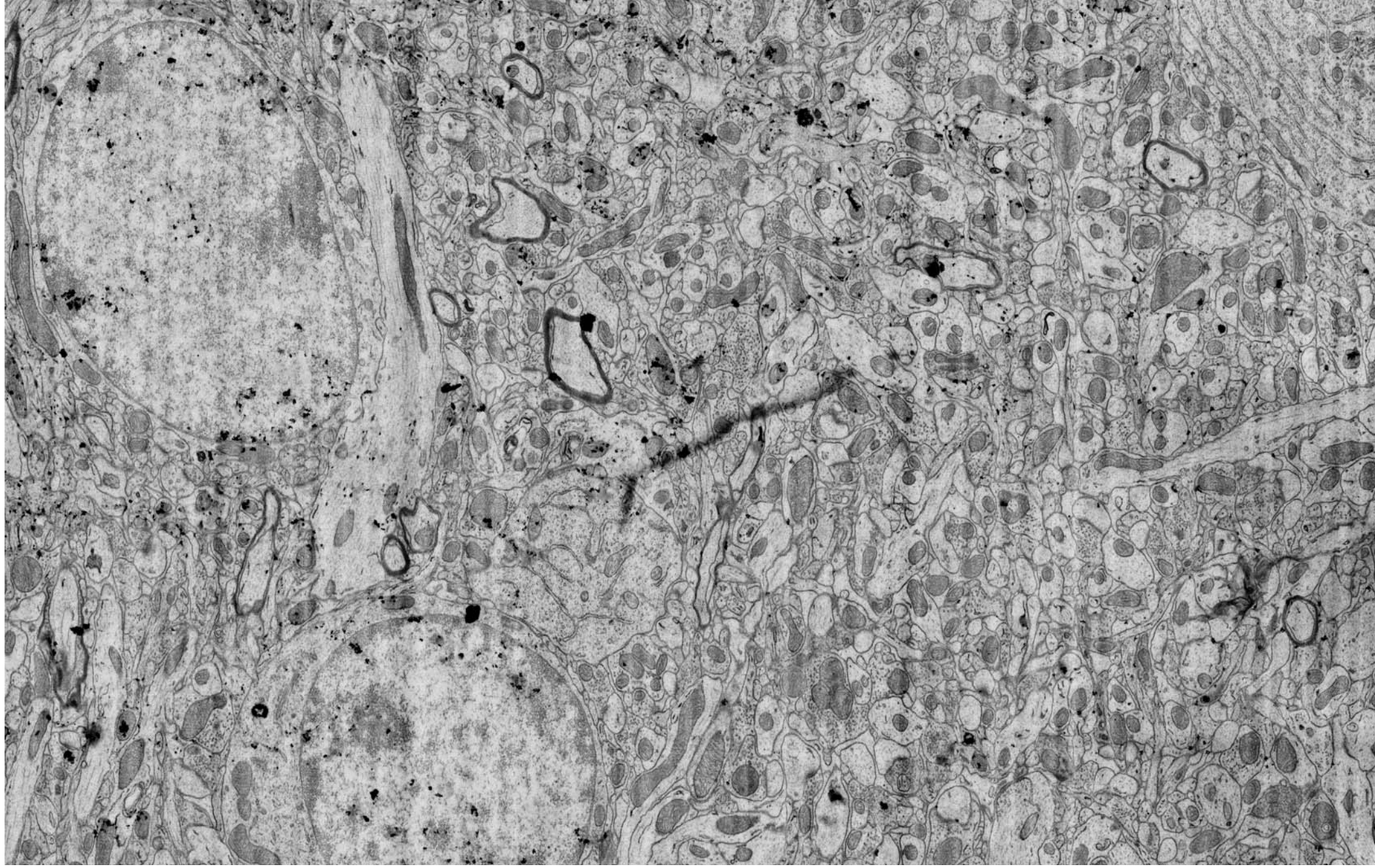
The possibilities offered by the complete detection system within the MERLIN® include the generation of in-situ 3 dimensional surface models.
The application example shows a surface deposition on silicon imaged with the AsB® detector (left).
The 3 dimensional surface models (right) generated in parallel during the image acquisition can be used for metrology investigations of the sample.

Applications in Life Sciences

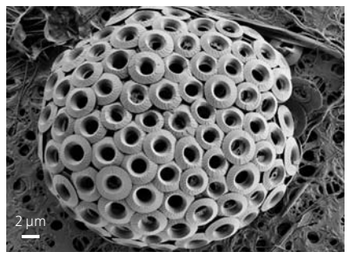
MERLIN® – Analytical Power for the Sub-Nanometer World

Ease of Use

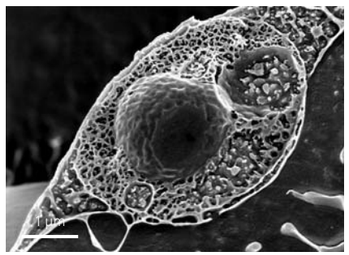
- With the highest beam current in a nm size spot, the MERLIN® system is the ideal instrument for rapid, large area, high resolution mapping of cell structures. Building on the leadership position established by FE-SEM solutions offering the largest image store resolution, the MERLIN® now provides the fastest imaging of large fields of view at FE-SEM resolution
- Automated column alignment for quickly attaining optimum imaging conditions gives even novice users the ability to achieve professional results
- View of up to 4 different detector signals at the same time for image comparison without alignment changes for all non-conductive biological materials due to unique charge compensation with in-situ cleaning
- Fastest Sub nm image acquisition including sample transfer in less than 60 seconds



*High resolution large area (16 k x 16 k pixels) backscatter image of a slice of a mouse brain. Imaged in a Σ*IGMA VE system with Fibics scan generator.
Building upon this success, the MERLIN® further extends this capability with superb resolution and image acquisition speed.
Courtesy of Dr. Jeff Lichtman and Colleagues, Harvard University.

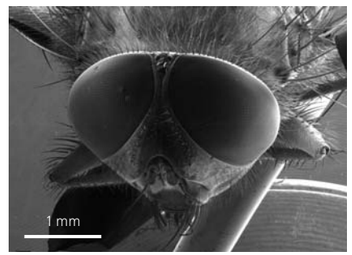


Radiolaria, imaged at 3 kV with lower Everhart Thornley detector.



The MERLIN® system can be equipped with different additional options for cryo applications. Image shows a cryo fracture of a tobacco leaf imaged at 2.6 kV with in-lens SE detector.

STEM bright field image of unstained myelin recorded at 30 kV acceleration voltage. Image shows unparalleled high contrast of the 4 nm axon layers.



Uncoated fly, imaged at 7.5 kV with local charge compensation, enabling the imaging of non-conductive samples without prior preparation.

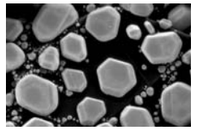
MERLIN®

Future assured with upgradeable building blocks for decades of first class system performance

- Upgradeable building blocks for decades of first class system performance
- Fastest, forward-design SEM electronics ready for future technology integration
- Upgradeable detection possibilities by plug & play solutions for years of leading edge technology integration

FE-SEM Platform

1 **GEMINI® II FE-SEM column**



Gold on carbon

2 **MERLIN® vacuum chamber with 15 accessory ports**
for unlimited additional analytical equipment integration

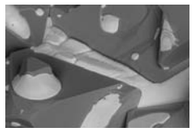
3 **Stage**
high precision motorized
- 5 axis or
- 6 axis (optional) stage systems
for highest precision navigation

4 **New forward-design SEM electronics**
ready for future technology integration

Complete Detection System

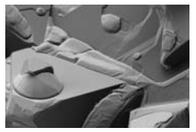
New Smart-detector building blocks design enables future integration of all detection systems via plug & play including:

5 **In-lens EsB® detector**
for highest material contrast



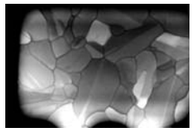
Compound of $Bi_2Ca_2Co_1$.

6 **In-lens SE detector**
for highest resolution information



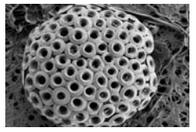
Compound of $Bi_2Ca_2Co_1$.

7 **AsB® detector**
for crystalline structure information



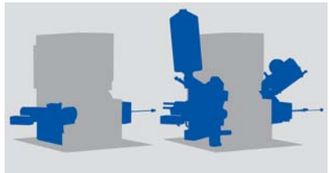
Polycrystalline silicon

8 **Chamber SE detector**
for topographical information

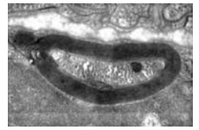


Radiolaria

Options and further options

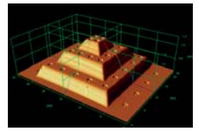


9 **STEM detector**
for high resolution images of TEM samples



Unstained myelin

10 **3D surface reconstruction system**
for 3D modeling of sample surfaces



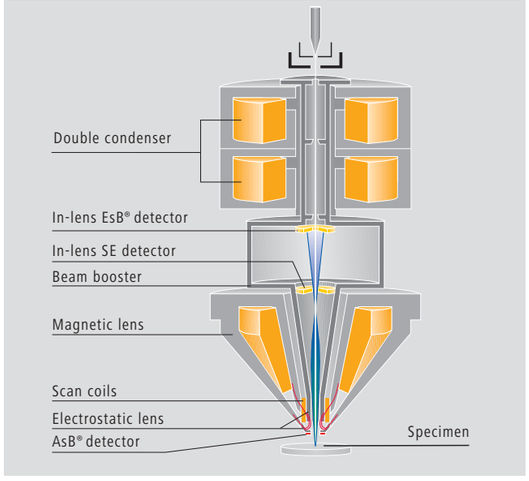
Calibration structure

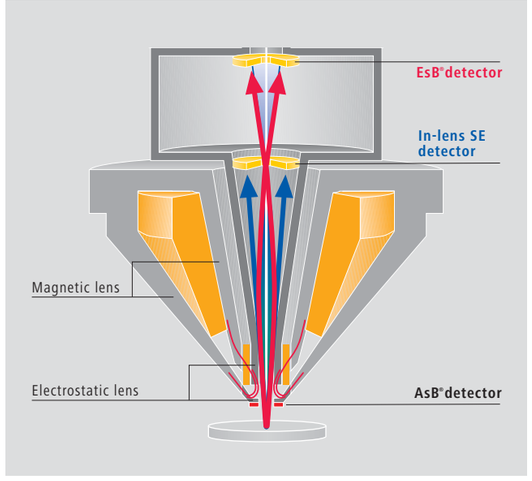
11 **Charge compensation with in-situ cleaning**

12 **Airlock** for fast and convenient sample transfer in less than 30 seconds
- 80 mm or
- 100 mm maximal specimen size

Further Options
EDX, EBSD, WDS, CI etc.

GEMINI® II Electron Optics
Complete Detection System





Schematic view of the GEMINI® II column. With minimum mechanical degrees of freedom the system is designed for maximum ease of use.

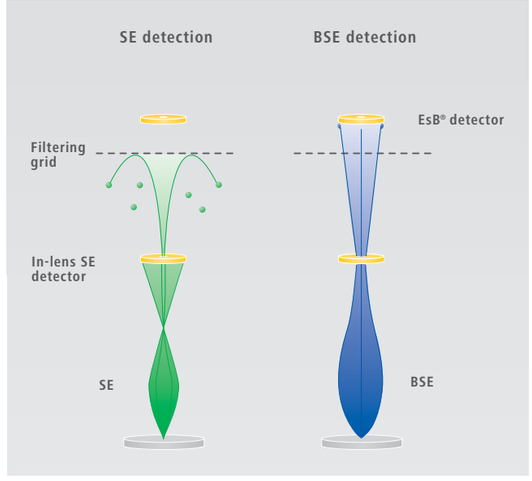
Complete detection system
The complete detection system combines three different detector systems for the analysis of all kinds of sample:

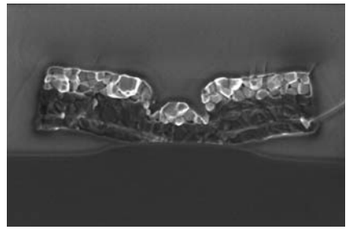
- **In-lens SE-detector** for high resolution imaging
- **In-lens Energy selective Backscatter-detector (EsB®)** for never-before-seen material contrast
- **Angle selective Backscatter detector (AsB®)** for crystalline analysis of the surface

Due to the new electronics of the MERLIN® all detector signals can be mixed together or viewed independently.

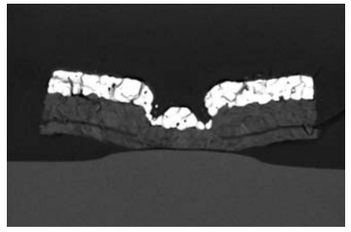
SE, EsB® and AsB® detection system
At the impact point of the primary electron beam, secondary and backscattered electrons are generated. The secondary electrons, with an energy of less than 50 eV, emerge from the very surface of the specimen. They contain surface information, as their angle distribution is almost perpendicular to the surface and orientation dependent. Due to their relatively low energy, SEs are attracted by the electrical field of the GEMINI® column and are all deflected by the excited objective lens to the plane of the annular in-lens SE detector. The SEs are detected across a wide angle range depending on the surface of the specimen.
Backscattered electrons carrying an energy close to the landing energy of the primary beam, are generated below the surface in a larger volume than the SEs. They contain highly specific information about the material composition of the sample. These high angle BSEs, typically in a cone with a 15° angle relative to the primary beam, are attracted by the electrical field of the GEMINI® column and projected into the column. Due to the difference in energy between secondary and backscatter electrons, they are accelerated by the beam booster on different trajectories within the column and the BSEs are deflected to a different plane. Here they are detected by an Energy selective Backscattered detector (EsB®) which additionally allows separation of BSEs, depending on their energy.
If the angle is too small the BSEs do not enter the column but will land on the objective lens pole piece, where they can be detected via the integrated AsB® detector. These low angle BSEs contain highly specific crystallographic information. Because of this Angle selective Backscatter electron detection, this detector is called an AsB® detector. The AsB® detector is completely integrated into the pole piece of the GEMINI® lens. This enables BSE imaging with an ultrashort working distance without additional alignment of the AsB® detector to the optical axis. This detector arrangement in the MERLIN® called "Complete detection system" enables the separation of SEs and BSEs. The latter can additionally be separated in low angle and high angle BSEs and an energy selective detection can be performed.

EsB® Filter Technology





In-lens SE detector for topographical information
The image shows a sectioned semiconductor. By design, the in-lens SE detector collects pure secondary electrons. Low energy secondary electrons originate only from the surface region.



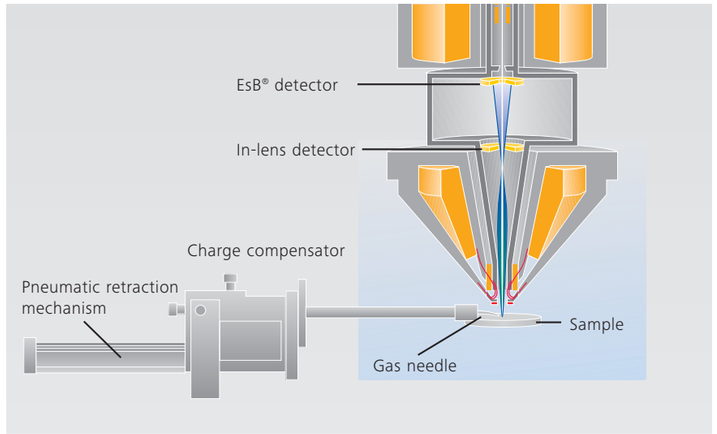
EsB® detector for material contrast information
The image shows the same sectioned semiconductor. By design, the higher energy backscatter electrons are detected with the in-lens EsB® detector.

Unique EsB® filter technology
The SEs and BSEs generated at the impact point of the primary electron beam are intercepted by the low electrical field of the GEMINI® column at the sample surface. They are accelerated by the field of the electrostatic lens. Due to the excitation of the objective lens the low energy SEs are projected onto the annular high efficiency in-lens SE detector. The high angle BSEs originating close to the impact point of the primary electron beam, are focused to cross-over at the hole of the in-lens SE detector and are detected by the integrated EsB® detector.
A small amount of SEs pass through the hole of the in-lens detector and would be observed by the EsB® detector.
To prevent detection of these SEs, a filtering grid is installed in front of the EsB® detector. By simply switching the filtering grid, the SEs are rejected and only the BSEs are detected. The unique combination of the inlens SE detector and the EsB® detector enables simultaneous imaging and mixing of clear high contrast topography (SE) and pure compositional contrast (BSE).
Below a landing energy of 1.5 kV the filtering grid has the additional function of selecting the desired energy of the BSEs. The operator can select the threshold energy of inelastic scattered BSEs to enhance contrast and resolution. For example, with a landing energy of 1.5 kV and the filtering grid on 1.4 kV, the SE is suppressed and the BSE landing energy on the EsB® detector is in the range of 1.4 - 1.5 kV.

Charge Compensation with In-situ Cleaning

With the new charge compensation with in-situ cleaning system, Carl Zeiss has engineered a unique solution for both:
imaging of nonconductive samples and in-situ cleaning of all types of sample.
Thanks to this unique solution, no preparation is needed for insulating samples. Users can insert virtually any kind of sample and start to image. Due to the additional possibility of in-situ sample cleaning during the imaging process, the requirement for sample cleanliness is kept to a minimum.

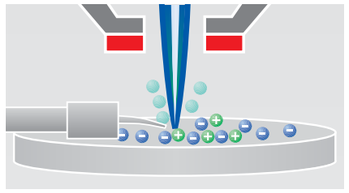
Charge compensation



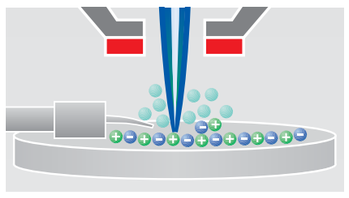
Fast change between local charge compensation and high vacuum operation is guaranteed by a simple pneumatic retraction mechanism for the gas injection system.

Charge compensation
The main part of the charge compensation system is a retractable pneumatic needle which can be automatically inserted in the sample's region of interest.

With this system, costly, time consuming sample preparation is no longer necessary. In addition, this charge compensation system enables full use of the "Complete detection system" of the MERLIN® FE-SEM; from SE detection to EsB® and AsB® detection, even with non-conductive samples.
This is a clear advantage: there is no longer any need for a high chamber pressure and therefore for the use of only low performance, low vacuum detectors.

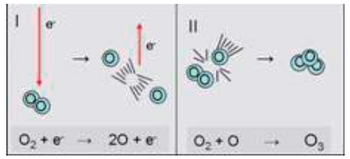


The sample surface is charged up by electron irradiation. The gas flow is turned on and the gas molecules (light green) form a local gas cloud above the sample surface.

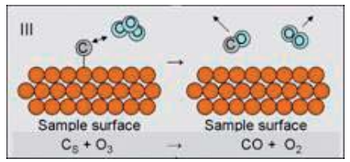


SE and BSE emitted from the sample surface ionize the gas molecules. As the resulting positive ions (dark green) hit the sample surface it is neutralized. Full imaging and analytical capabilities are thus enabled.

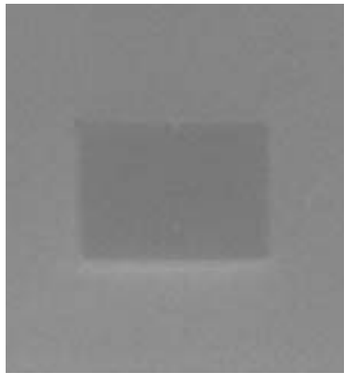
In-situ cleaning



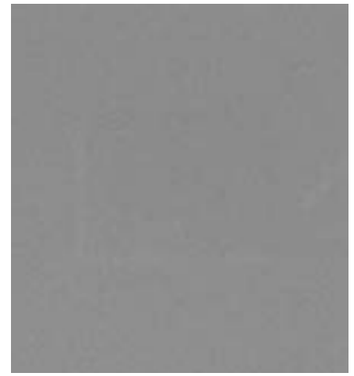
Principle of electron introduced Ozone generation.



Principle of Ozone introduced surface cleaning.



Left: Carbon contamination on silicon wafer generated via electron beam dissociation of hydrocarbons.



Right: By using the charge compensation-unit for in-situ cleaning all carbon impurities are removed in-situ during imaging.

In-situ cleaning
Hydrocarbons are present in trace levels on any material because all surfaces exposed to ambient air at atmospheric pressure accumulate hydrocarbons.
A powerful solution to remove hydrocarbon contamination is possible by using the unique charge compensation with in-situ cleaning. The in-situ cleaning mechanism is shown in the images I - III: When a constant oxygen flow is introduced via the charge compensation-unit, the high energy electron beam collides with an oxygen molecule and splits it into two free oxygen atoms (I).

In the next step the free single oxygen radicals react with other oxygen molecules to form highly reactive ozone molecules (II). If the investigated surface sample is contaminated with C impurities, the ozone (O_3) molecule reacts with the carbon on the surface sample (C_S) resulting in carbon monoxide (CO) and oxygen (O_2) and a clean sample surface.
The fully automated technical setup of the charge compensation-unit allows the cleaning process to be implemented during imaging.

MERLIN®
Technical Data

Essential Specifications	MERLIN®
Resolution (optimal WD) *All resolution specifications are dependent on the system configuration.*	0.8 nm @ 15 kV 1.4 nm @ 1 kV 3.0 nm @ 20 kV at 10 nA, WD = 8,5 mm 0.6 nm @ 30 kV (STEM mode)
Acceleration Voltage	0.02 – 30 kV
Probe Current	10 pA up to 300 nA (depending on system configuration)
Magnification	12 – 2,000,000 x in SE mode 100 – 2,000,000 x with EsB® detector
Electron Emitter	Thermal field emission type, stability > 0,2 % / h
Detectors	High efficiency in-lens SE detector Everhart Thornley Secondary Electron detector EsB® detector with filtering grid, filtering voltage 0 – 1500 V Integrated AsB® detector
Specimen Stage	5-Axes Motorised Eucentric Specimen Stage X = 130 mm Y = 130 mm Z = 50 mm T = -3° to 70° R = 360° (continous) Further additional optional stage systems available
Chamber	330 mm (Ø) x 270 mm (h) 15 accessory ports for various options including STEM, 4QBSD, EBSD, EDS, WDS CCD-Camera with IR-illumination Charge compensation with in-situ cleaning
Image Processing	Resolution: Up to 6144 x 4608 pixel (32 k x 32 k pixel optional available) A large number of integration and averaging modes available
Image Display	Single 19'' TFT monitor with SEM image displayed at 1024 x 768 pixel
System Control	SmartSEM® with Windows®XP, operated by mouse, keyboard, joystick, control panel

= upgrades

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