SUPRA® Series

Ultra High Resolution FE-SEM for Versatile Analytics

We make it visible.
Maximize Information – Maximum Insight

More than 160 years of experience in optics has laid the foundation for pioneering 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.

Superbly equipped, 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.

Our mission at all times: Maximum Information – Maximum Insight.

**SEM**
Scanning Electron Microscopes

**FE-SEM**
Field Emission - Scanning Electron Microscopes

**HIM**
Helium Ion Microscopes

**CrossBeam**
CrossBeam Workstations (FIB-SEM)

**TEM**
Transmission Electron Microscopes

**SUPRA® Series**
The flexible FE-SEM concept - comprehensive ultra high resolution and analytical solutions for Materials Analysis, Life Sciences and Semiconductor Applications

One for all – the most versatile FE-SEM family currently available

Facing the daily challenge – the workhorse for routine examinations, failure analysis, process control and cryo applications

High end research – superb imaging and excellent analytical capabilities with unsurpassed long term probe current stability

Adaptable to all tasks – flexible design concept with versatile GEMINI® column and unique specimen chamber design

High comfort with easy operation mode – intuitive graphical user interface combined with ease of use GEMINI® column

See page 12 for the original application image.
The versatile SUPRA® instrument family

SUPRA® 40/40 VP
The SUPRA® 40 is an ideal solution for many applications such as failure analysis, process control, cryo, and nanoanalysis. With the well balanced combination of a large eucentric stage, analytical multi-ported chamber, extended performance GEMINI® column and variable pressure capabilities it represents the versatile workhorse of the SUPRA® family. The variable pressure technology for FE-SEM, together with the unique VPSE detector allows high voltage imaging and analysis of non-conducting specimens without prior preparation.

SUPRA® 55/55 VP
The SUPRA® 55 offers the highest resolution available today, comparable with „in-lens instruments“, combined with a superb large fully eucentric 5” stage and a large multi-functional specimen chamber. The SUPRA® 55 has been designed for the most demanding applications in nanotechnology with sub-nm resolution readily attainable.

SUPRA® 60/60 VP
The large cylindrical chamber with a refined 6” super eucentric stage and 8” integrated airlock offers the perfect solution for full wafers and cross sectional semiconductor applications, and for users who need to image a variety of large samples. The SUPRA® 60VP makes it possible to image non-conducting specimens without specimen coating, therefore minimising preparation time and increasing throughput.
Electron Source Performance Comparison

**Table 1: SFE Source Performance Comparison**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emitter Type</th>
<th>Cold FE</th>
<th>Schottky FE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathode material</td>
<td>W</td>
<td>2,800</td>
<td>200 (10)</td>
</tr>
<tr>
<td>Operating temperature [K]</td>
<td>L</td>
<td>1,900</td>
<td>14,600</td>
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<tr>
<td>Cathode radius [m]</td>
<td></td>
<td>10,000</td>
<td>10,000</td>
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<tr>
<td>Effective source radius [m]</td>
<td></td>
<td>5,000</td>
<td>6,000</td>
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<tr>
<td>Emission current density [A/cm²]</td>
<td>300</td>
<td>0.5</td>
<td>0.8</td>
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<tr>
<td>Normalised brightness [A/cm².sr.kV]</td>
<td>1000</td>
<td>1.50</td>
<td>1.30</td>
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<tr>
<td>Maximum probe current [μA]</td>
<td></td>
<td>40</td>
<td>2,2</td>
</tr>
<tr>
<td>Energy spread at the cathode [eV]</td>
<td>1000</td>
<td>2.10</td>
<td>5.10</td>
</tr>
<tr>
<td>Energy spread at the anode [eV]</td>
<td>1000</td>
<td>0.27</td>
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<tr>
<td>Beam noise [%]</td>
<td>0.50</td>
<td>0.2</td>
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<tr>
<td>Emission current drift [%]</td>
<td>0.1</td>
<td>0.5</td>
<td>0.2</td>
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<tr>
<td>Operating pressure [Pa]</td>
<td>5 x 10⁻⁵</td>
<td>200</td>
<td>200</td>
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<tr>
<td>Effective brightness [μA/cm².sr.kV]</td>
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<td>Beam brightness [A/cm².sr.kV]</td>
<td>100</td>
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<td>Sensitivity to external influence</td>
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</table>
Ultra high performance objective lens

The GEMINI® objective lens provides outstanding resolution and image quality, especially at low beam voltages, without any compromise in operational convenience.

**GEMINI® Objective lens**

The SUPRA® has been built around the unique GEMINI® lens design which has many advantages over classical lens designs:

- The most important feature is the decreasing aberrations with decreasing beam energy. Therefore it delivers superb resolution down to 20 V and at 30 kV its resolving power is unsurpassed.
- The high-angled GEMINI® objective lens body allows 50° tilt of large specimens (e.g. 6” wafers) at a working distance as low as 6 mm. The analytical working distance for 2D analysis with a take-off angle of 35° is only 8.5 mm — suitable for high resolution imaging. The GEMINI® objective lens consists of a high performance magnetic lens with an inserted electrostatic lens. The GEMINI® concept has overcome the problem with classical objective lens designs which immerses the specimen in the magnetic field of the objective lens. Classical FE columns tend to have low magnetic fields of the objective lens. Therefore, high resolution imaging of dia-para- or ferromagnetic samples is possible with very short working distances. The magnetic/electrostatic lens combination is equivalent to a perfect magnetic lens which increases the incident beam aperture angle at the specimen and hence improves resolution. The increase of the optimum beam aperture angle also provides a larger electron probe current and hence generates a superior signal to noise ratio of the image. The lens control system with integrated condenser control enables the operator to select the optimum beam aperture for any combination of working distance and/or selected energy. Consequently the GEMINI® delivers excellent image contrast even at the resolution limit. A single-stage beam scanning system is integrated in the GEMINI® lens, just in front of the electrostatic lens gap. Therefore, the transverse chromatic and other scanning aberrations have been minimised. The instrument operates without distortion at TV-scanning speed from the lowest (12 A) to the highest (1,000,000 A) magnification. In particular, no switch-over is required between a low magnification mode and a high resolution mode.

**High efficiency SE signal detection**

The GEMINI® objective lens concept allows optimum detection of all signals generated at the specimen.

**SE**

Excellent efficiency detection of the secondary electron (SE) signal is another benefit of the GEMINI® lens concept. The low energy, secondary electrons generated at the impact point of the primary electron beam are intercepted by the weak electrical field at the sample surface. They are then accelerated to a high energy by the field of the electrostatic lens and focused on the annular in-lens detector inside the beam booster located above the objective lens. The GEMINI® column used with the SUPRA® range of FE-SEMs now benefits from the 3rd generation of in-lens detectors with increased signal to noise ratio, improved dynamic range and no aging effect on the detection material. While the in-lens detector provides the best high resolution information, a lateral SE detector in the specimen chamber provides optimum topographical information. Signals from both detectors may be mixed to deliver optimum image quality.

*For the variable pressure (VP) instruments ZEISS has developed the unique VPSE detector to enable SE imaging at pressures in the 2 to 133 Pa range combined with the standard Everhart-Thornley detector for imaging in high vacuum (HV) mode.*

The GEMINI® column allows optimum detection of back-scattered electrons (BSE) because of the absence of an immersion field of the objective lens. Classical FE columns tend to condense the BSE on the optical axis in the same way as it condenses the primary electrons. With the GEMINI® column a high probe current can be focused on a small spot, even at low beam energies, allowing BSE images and X-ray mapping with much better resolution than ever before.
The SUPRA® range delivers extraordinary results for semiconductor applications. The SUPRA® 40/40VP and the SUPRA® SSVP models are designed to meet the most demanding applications of semiconductor failure analysis and process development. Imaging of non-conducting specimens, cross sections or assemblies present no problems for the SUPRA® FE-SEM.

- Ultra high resolution imaging at low kV to avoid charging. The high efficiency in-lens detector with its large dynamic range and short acquisition times enables contrasts never seen before.
- Variable pressure at the specimen level to neutralise charging of the specimen. True SE imaging with the unique enhanced VPSE detector.

The ultra high resolution GEMINI™ column delivers a resolution level comparable with “in-lens” instruments, but with the versatility of examining large specimens. The large 5-axes motorised stage gives full flexibility to handle large awkwardly shaped specimens or to load a number of small samples to increase productivity. The SUPRA® 60 and 60VP models with the 6” super eucentric stage, the large specimen chamber and the 8” airlock are designed to handle 6” and 8” wafers. With the VP model the pressure at the specimen level can be controlled between 2 and 133 Pa to neutralise specimen surface charging and to avoid any surface damage.

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For material analysis applications in nano technology, developing new materials and materials characteri-
sation the SUPRA® offers the most versatile ultra high
desolution analytical FE-SEM available. The GEMINI®
column technology is now capable of resolving structu-
res on a resolution level comparable with “in-lens”
struments. With the same column high current
mode, probe currents are delivered to meet any analy-
tical application ranging from BSE, CL, EDS, EBSD to
WDS without sacrificing resolution capabilities. The
new SUPRA® combines four instruments in one: ultra
high resolution FE-SEM over the complete voltage
range, FE-SEM for handling large awkwardly shaped
specimens, full analytical FE-SEM with probe currents
up to >20 nA achievable and the VP (variable pressure)
technology to investigate non-conducting specimens
without prior preparation.

Another unique benefit of the GEMINI® technology is
the extremely low magnetic field outside the objective
lens compared to the single pole FE-SEM electron
optics. The GEMINI® column enables ultra high
-resolution distortion free imaging of magnetic
specimens.

Especially for materials analysis applications the
SUPRA® with its GEMINI® column offers the widest
configuration of instruments.

All instruments comprising fully motorised
stages and analytical specimencambers
with a multitude of ports to adapt a range
of analytical detectors for simultaneous
imaging and analysis.
Excellence in diagnostics

The SUPRA® series with the GEMINI® field emission column has excellent low voltage imaging capabilities. Low voltage imaging with low dose energy avoids surface damaging of delicate biological samples. The efficient signal collection and the high contrast dynamic range of the GEMINI® column is particularly useful for low contrast biological samples. With the VP (variable pressure) mode on the SUPRA® 40VP or SUPRA® 55VP non-conducting biological samples can be imaged without prior preparation saving time and avoiding possible artefacts introduced with specimen preparation like drying, fixation and conductive coating. Another major application for biological specimens or colloid chemistry is cryo-SEM. The SUPRA® range has a large cryo port for adaptation of cryo systems on the chamber or a cryo shuttle with off-chamber cryo preparation. With the SUPRA® superb high resolution imaging capabilities it is now possible to image details previously only seen with replicas in the TEM.

Immuno gold labelling of antibodies with 10–20 nm Au. Imaging voltage 980 V on uncoated specimen; the gold labelling is clearly visible on the outside of the membrane.

Overview of diatom with digitally zoomed details. The fine spot size of the GEMINI® column combined with the large 3072 x 2304 pixel frame store allows high resolution imaging at low magnification. The three insets show details of the centre (right inset), middle (middle inset) and outer area of the diatom.

Image courtesy of Prof. Dr. Manfred Sumper, Inst. of Biochemistry I, University of Regensburg, Germany.

Non coated proto-collagen grown on carbon. The image was taken with 390 V in HV mode and shows the contrast between hydrocarbons and carbon foil.

Cryo fracture of tobacco leaf, showing excellent contrast at 2.6 kV with the in-lens detector. The Cryo prepatration system was interfaced via the cryo port onto the SUPRA® 40VP chamber.

High resolution image of fresh yeast at 1.5 kV with the in-lens detector. Transmembrane protein crystals with layers of previously unseen protein arrays smaller than 3 nm. With the SUPRA® fast results can be achieved which are comparable with time consuming and complicated replica/TEM work.

Life Science applications

Image of eluate with the in-lens detector at 4 mm WD showing fine details and high depth of focus.

Low magnification image at a long working distance. This image illustrates the excellent high signal level in VP mode at 20 Pa without any shadowing on this highly topographic sample.

Non coated proto-collagen grown on carbon. The image was taken with 390 V in HV mode and shows the contrast between hydrocarbons and carbon foil.
The proprietary VP (variable pressure) technology for the GEMINI® column enables many applications for direct imaging of non-conductive or delicate specimens without complicated sample preparation techniques. The VP technology is available on the SUPRA® 40VP, SUPRA® 55VP and the SUPRA® 60VP. Operation of high vacuum mode or variable pressure mode is simply selected by mouse click.

In high vacuum mode the SUPRA® VP instruments deliver the same excellent resolution as the non VP models. In variable pressure mode the enhanced VPSE detector enables true SE imaging even at longer working distances. A BSE detector positioned underneath the objective lens allows simultaneous SE and BSE detection for topographic and material contrast imaging.

Enabling solutions

VP applications on non-conducting specimens
VP FE-SEM
Explore the extra dimension with the unique variable pressure (VP) mode for the GEMINI® field emission column which brings many advantages for imaging non-conducting specimens, without charging artefacts:

- Superb ultra high resolution in high vacuum mode.
- Ultra high resolution in variable pressure (VP) mode – 2.0 nm @ 30kV.
- Non-destructive artefact-free imaging and analysis of samples in their natural state.
- Increased productivity, saves costs by eliminating complicated preparation.
- Optimum secondary electron detection in all modes with high efficiency in-lens detector in high vacuum mode and enhanced VPSE detection in VP mode.
- Fully automated vacuum system, with simple click selection of mode and desired pressure.
- Non-charging imaging of insulating specimens using analytical conditions - 15 to 30kV.
- Investigation of moist samples using a Peltier cooling stage.

The SUPRA® series VP detection system configuration offers four imaging detectors available at any time:

1. In-lens SE detector for SE1 electron detection in HV mode
2. Enhanced VPSE detector for true SE imaging VP mode
3. Everhart-Thornley detector for SE imaging in HV mode
4. BSE detector (optional) for imaging in HV and VP mode

VPSE Detector
The VPSE - Variable Pressure SE detector
Since the standard lateral secondary electron detector (Everhart-Thornley type) and the high efficiency in-lens detector are both designed for use in high vacuum, secondary electrons cannot be detected by these detectors in VP mode. The solution has been to develop the unique enhanced VPSE (Variable Pressure Secondary Electron) detector to allow true secondary imaging under both normal and variable pressure conditions. An optional BSE (Backscattered Electron) detector can be used to obtain additional image information.

The extra dimension with variable pressure FE-SEM technology

The VP vacuum System of the SUPRA® FE-SEM.

The VP vacuum System of the SUPRA® FE-SEM.

Supra® VP vacuum system
The specimen chamber and the GEMINI® column are divided into four pressure regions separated by pressure limiting apertures. The vacuum in the field emission emitter area and the upper part of the GEMINI® column is maintained by two ion getter pumps, the lower part of the column is pumped by a turbomolecular pump (TMP). The specimen chamber can be separated from the TMP vacuum by a chamber isolation valve (CIV). As soon as a VP mode is selected, the system automatically regulates the chamber pressure and additionally selects the variable pressure SE detector for you. An automatic feed back loop ensures that the new pressure is accurately set and regulated in the specimen chamber. With a single mouse click high vacuum can be selected if required.

Collision of the Secondary electrons with gas molecules produces positive ions near the sample surface. The ions are combined with excess electronic charge on the surface. This leads to a neutralisation of the charging surface.

VP - Variable Pressure SE detector
Since the standard lateral secondary electron detector (Everhart-Thornley type) and the high efficiency in-lens detector are both designed for use in high vacuum, secondary electrons cannot be detected by these detectors in VP mode. The solution has been to develop the unique enhanced VPSE (Variable Pressure Secondary Electron) detector to allow true secondary imaging under both normal and variable pressure conditions. An optional BSE (Backscattered Electron) detector can be used to obtain additional image information.

Secondary electrons are accelerated away from the sample surface and collide with the gas molecules in a collision zone to create further electrons which are also accelerated in the electrical field. The avalanche of secondary electrons provides amplification of the SE signal. In addition to ions, secondary electron collisions also produce photons. These photons are collected by the VPSE detector to produce a true secondary electron image. Although BSE also cause collisions their contribution is less than 1% of the low energy SE, ensuring that the VPSE is genuinely secondary electron imaging.
SUPRA® ultra high resolution analytical FE-SEM

**EDS**

The SUPRA® series of field emission SEMs all combine ultra high resolution imaging with full analytical capabilities. The compact GEMINI® objective lens enables an analytical working distance of only 8.5 mm with a take-off angle of 35°. The short working distance together with the high take-off angle are ideal to combine high resolution imaging with full quantitative EDS analysis.

SUPRA® plus EDS offers:
- EDS analysis fully compatible with other imaging detectors
- Simultaneous EDS/WDS, either fully focussing or compact X-ray optics type
- Fully quantitative EDS analysis
- Fully automatic inclusion 8 particle analysis with elemental mapping
- EDS analysis on non-conducting specimens in VP mode

**WDS**

The SUPRA® SS/WDS has been designed to meet the most demanding analytical applications. The new anode configuration combined with the high current mode lens control provide sample probe current to perform WDS analysis. The chamber design with 35° take-off angle allows simultaneous WDS and EDS analysis with SE, BSE, STEM, CL and SCM imaging.

The GEMINI® column enables WDS analysis with a high current in a small spot combined with a superb beam stability. The WDS spectrometer with high sensitivity for light elements, superior energy resolution (1-20 eV), low background and 10x higher intensity for elemental analysis offers analytical solutions beyond EDS analysis.

The combination of the SUPRA® SS together with the WDS spectrometer opens new fields of applications for high spatial resolution X-ray analysis.

With the SUPRA® SS VP-Version even non-conducting samples can be imaged and analysed with EDS in variable pressure mode, however WDS analysis has to be performed in high vacuum mode.

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Chamber view of SUPRA® SS/WDS showing EDS, WDS and BSE detector for simultaneous imaging and analysis.

SEM image with EDS mappings.

Spectrum display shown with spectrum overlay.

EDS/WDS spectra, showing superior energy resolution of WDS without any
CL and EBSD applications

CL

Cathodoluminescence (CL) imaging and spectroscopy has found many applications in the field of mineralogy, geology, ceramic materials research and the development of luminescent materials.

The results shown on this page were produced using the SUPRA® 40 and the SEM CL spectrometer system with an ellipsoide mirror collector. The high current density of the GEMINI® column delivered in the fine probe enables high resolution CL imaging at low kV. The stage and specimen chamber design of the SUPRA® series offer ample space to adapt the SEM CL system without blocking other detectors.

CL spectrum of the detailed area using the SUPRA® 40 with the SEM CL spectrometer.

By using the GEMINI® Multi-mode STEM detection system, the information limit for the SUPRA® FE-SEM can be extended beyond the nanometer range. A resolution of 0.8 nm is now readily attainable and gives additional nano scale information. The quality of the image obtained with the STEM unit are similar to images obtained by a TEM with a scanning attachment.

The GEMINI® Multi-mode STEM unit unique features are:

- Improved resolution by reducing the excited volume and compared with TEM imaging no chromatic aberration introduced by the projection lens system.
- Contrast enhancement due to increased cross sections for lower accelerating voltage.
- Unique contrast tuning for low contrast specimens.
- Parallel detector arrangement allows simultaneous Real-time imaging and mixing of BF, DF and orientated DF signals.
- Small excited volume in thin sections results in dramatic improvement of resolution for EDS analysis, enabling nano-particle analysis.

EBSD

EBSD is an important tool for materials characterisation today showing the crystal structure and the texture of polycrystalline materials in the form of crystal orientation maps (COM). The SUPRA® with the large analytical chamber and the high current GEMINI® column is ideally suited to perform EBSD. All SUPRA® specimen stages offer high stage tilt needed for EBSD investigation with the EBSD detector mounted on the left of the specimen chamber normal to the tilt axis. The EDS detector is positioned above the EBSD detector at 35° take-off angle to allow simultaneous data collection. For this important analytical application the SUPRA® is the perfect tool combined with unparalleled ultra high resolution imaging.

EBSD

Forward scattering BSE image of barely deformed extruded copper.

Constant potential image of Cu 200 kV, 100 nA, 10s.

EBSD in normal direction

EBSD in rolling direction

EBSD in transverse direction

STEM image of polymer to illustrate the resolving power of the STEM detector.

STEM image of microtubals forming nematodesmal rods.

Both specimen by courtesy of Institut for special Zoology Tübingen

GEMINI® Multi-mode STEM detection system

STEM image of oral basket of Pseudomicrothorax spec. Ciliata nasulida.
Integrated Computer Environment

ICE

More than simply a digitally interfaced add-on PC, ICE merges the hardware and software of the microscope so that every operating parameter is available for control or automation. ICE means real-time response to operator command, true self-monitoring and the practical realisation of remote microscopy through NetSEM™.

Fast results are achieved through the intuitive SEM interface using the mouse and keyboard and, for those who prefer the tactile response of rotary controls, a multi-function control panel is available.

Great results can only come from a self monitoring system that responds immediately and intelligently to operational changes. Setting the imaging parameters to their optimal value always delivers performance.

Communication made simple, with NetSEM™ Remote SEM operation, data filing and printing over a local area network and FTP remote printing through the Internet.

It couldn’t be simpler, load a template - press F9 and instantly generate a report including the image.

This possibility can only exist when the SEM control software is totally Windows® compatible, and all of the SEM parameters are available through the PC.

Communication made simple, with NetSEM™ Remote SEM operation, data filing and printing over a local area network and FTP remote printing through the Internet.

It couldn’t be simpler, load a template - press F9 and instantly generate a report including the image.

Three real-time image filtering modes and further image processing capabilities ensure that even images collected from difficult samples are crisp and incredibly detailed.

High resolution images, with square pixel, of up to 3k x 2k in size can be captured, essential for desk top publishing and image analysis techniques. Images can also be stored in BMP and JPG format.

Great results can only come from a self monitoring system that responds immediately and intelligently to operational changes. Setting the imaging parameters to their optimal value always delivers performance.
Would you like to have a product demonstration? Are you looking for application support? Please do not hesitate to contact us for an appointment to visit one of our superbly equipped demo centers. You can find us in the following locations: Germany (Dresden and Oberkochen), USA (Peabody), France (Nanterre), UK (Cambridge), Japan (Yokohama) and in Singapore. We look forward to seeing you! You can find an overview with contact details online at www.smt.zeiss.com/democenter

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