

12 Years Zeiss Gemini® FESEM Technology

The Nano Technology Systems Division of Carl Zeiss SMT, based in Oberkochen, Germany, provides its customers with total solutions featuring the latest leading edge EM technology. The company's extensive know-how, acquired over 60 years in the field of E-beam technology, has brought many innovations to the market. A good example for this is the Gemini based Field Emission SEM. Introduced by Zeiss 12 years ago, this has proven to be one of the most versatile FESEM systems on the market today. The latest Supra* and Ultra series of FESEMs of Carl Zeiss SMT are all based on the now 3rd generation Gemini column. The drive to develop the Gemini technology was the need for an ultra high resolution FESEM at very low voltages, but with the flexibility needed for a wide range of analytical applications.

With the Gemini technology, Zeiss has overcome the main limiting factors of SEM resolution:

- Probe diameter at the sample surface – the smaller the probe size, the better the resolution, hence the need for a FESEM column
- Depth of penetration of the electron beam into the specimen surface – deeper penetration gives a larger interaction volume and degrades resolution: ultra low voltage capability is the solution
- Probe current – higher probe currents give better signal to noise ratio: high current module
- Detector efficiency – higher efficiency gives better contrasts and higher signal to noise ratio: In-column detectors to improve resolution

The Gemini column comprises a number of unique features, like the integrated beam booster, the magnetic / electrostatic objective and annular In-column detectors. It has imaging capabilities comparable with in-lens FESEMs without specimen size limitations.

Gemini FESEM Column Design

The Schottky FE source used in the Gemini column achieves a similar low energy spread as the cold field emission source, but with a much higher emission current coupled to a much higher beam stability. Regeneration of the beam tip (flashing) is not required. The Gemini column features the unique integrated

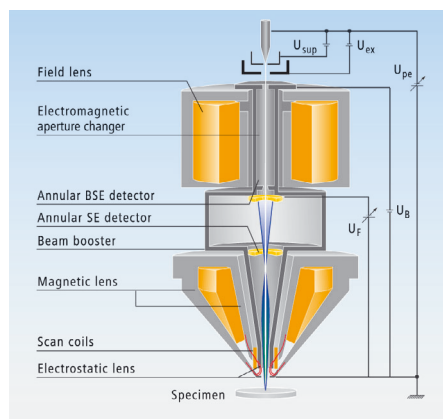


Fig. 1: Cross section of the Gemini electron optical column utilised in the Ultra FESEM.

U_{ex} – extractor voltage of first anode
U_{pe} – primary beam voltage
U_B – booster voltage
U_F – EsB filtering grid voltage

beam booster to keep a relatively high accelerating voltage in the column. Furthermore, the electron beam path is designed without any cross over between electron source and specimen surface (Fig 1).

Ultra Low Voltage

Imaging Capabilities

One of the most important advantages of the Gemini column is the decreasing aberrations with decreasing beam energy. This ensures superb resolution even at ultra low voltages (Fig. 2).

The magnetic / electrostatic lens combination increases the incident beam aperture angle at the specimen which

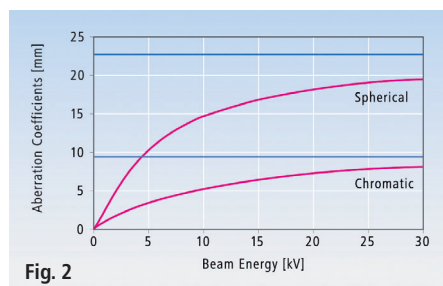


Fig. 2

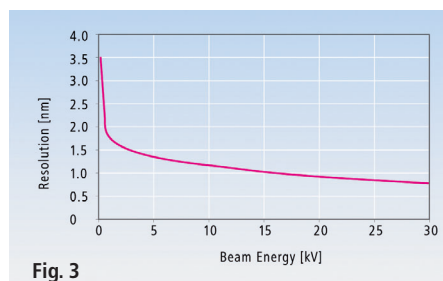


Fig. 3

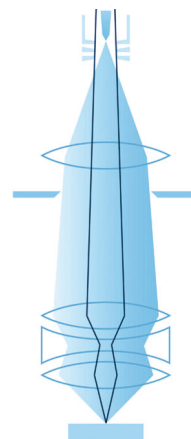


Fig. 4: Beam profile comparison, note virtual parallel illumination with high current mode (narrow beam).

improves both the signal to noise ratio and the resolution (Fig. 3).

The Gemini lens is shaped to minimise the magnetic field at the specimen. Therefore the high resolution imaging of dia-, para-, or ferromagnetic materials is possible with very short working distances.

Gemini High Current Module

A further development of the Gemini column has resulted in the unique

high current mode which allows for doubling the current, compared to the standard operating parameters. The high current in a smaller beam diameter gives a virtual parallel illumination (Fig. 4), which greatly increases depth of focus. The advantages for analytical applications, EBSD and imaging of topographic specimens are obvious: Fig 5a/b.

In-column Detectors

The Gemini column design includes an integrated In-lens SE detector. The weak magnetic field at the specimen surface intercepts the low energy secondary electrons (SE) at the point of impact. They are then accelerated in the booster column and focused on the In-lens above the objective lens. The recently introduced 3rd generation of In-lens detectors boost increases signal to noise ratio (factor 2–3 improvement), improved dynamic range and does not suffer from ageing. Following Carl Zeiss SMT philosophy to protect customers investments, the improved high efficiency In-lens SE detectors are compatible with most of the installed Gemini systems (1500 and 982 series).

New Gemini Based FESEM: Ultra

The Ultra FESEM, introduced last year, is based on the successful Supra series FESEM and features a second In-column detector, enabling simultaneous detection of backscatter electrons (BSE) with

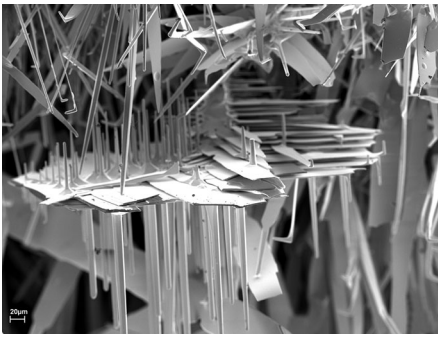


Fig. 5a: Normal imaging on high topography sample. The sample is 4mm high and was acquired at 4mm working distance and 1.2kV. Although the Gemini column is still superior to other systems under these conditions, the limited depth of field is noticeable.



Fig. 5b: Using the HC/DoF module gives a dramatic improvement of the depth of field under the same conditions as in Fig.5a. Even with a height of 4mm, the complete sample is in focus.

the newly developed EsB detector. The energy and angle selective Back-scatter detector is positioned directly above the In-lens SE detector. The difference in energy and emerging angle at the specimen surface of the SE and the BSE allows for effective separation in the Gemini column precisely at the plane of the In-lens SE detector (Fig. 6). The BSE pass the central aperture and are then projected on the EsB detector (Fig.7). To avoid any unwanted overlay with SE electrons, a filtering grid is installed in front of the EsB detector to repel the SE which have passed through the In-lens aperture. Ad-

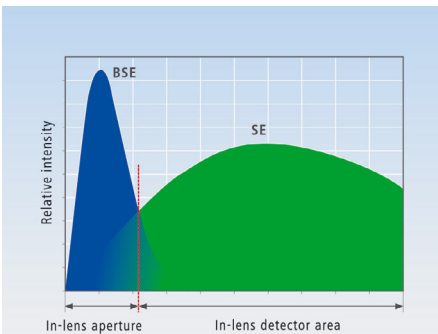


Fig. 6: Radial distribution of BSE and SE in the In-lens detector plane. Clearly visible is the separation of the electrons at the In-lens SE detector plane and the high detection efficiency of both detectors.

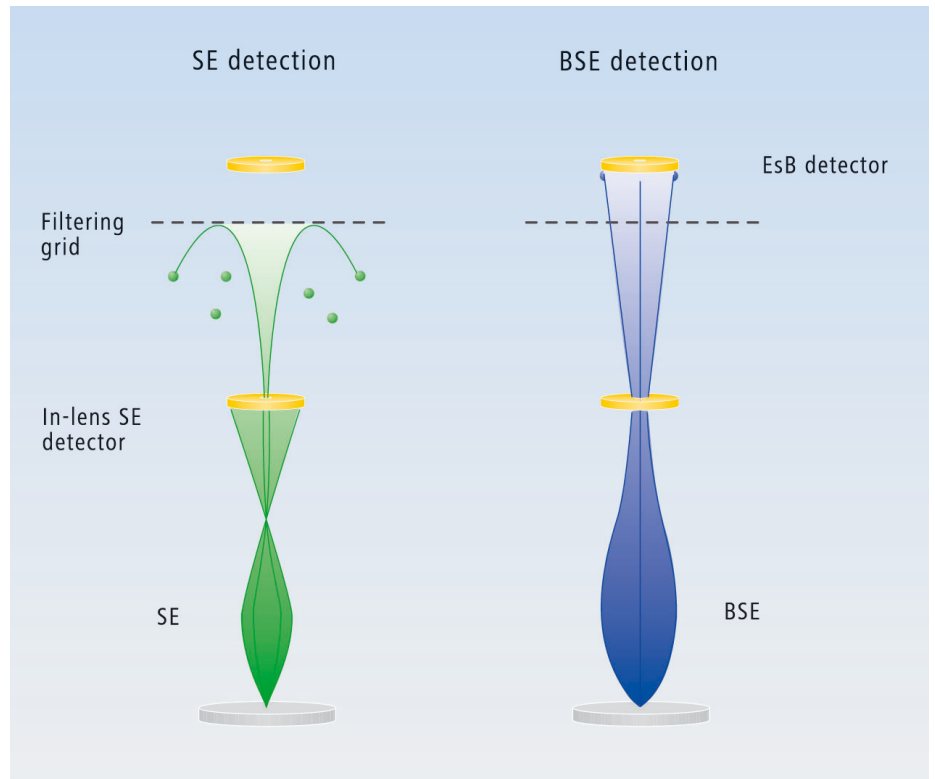


Fig. 7: The SEs (green) are projected onto the high efficiency In-lens detector and the BSEs (blue) are guided onto the integrated EsB detector.

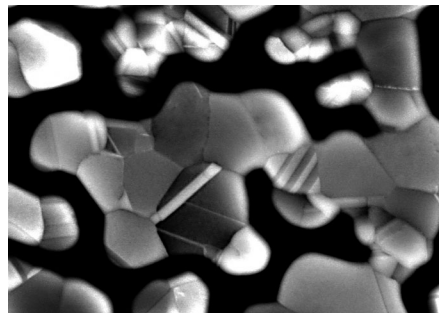


Fig. 8: Au-particles (BSE).

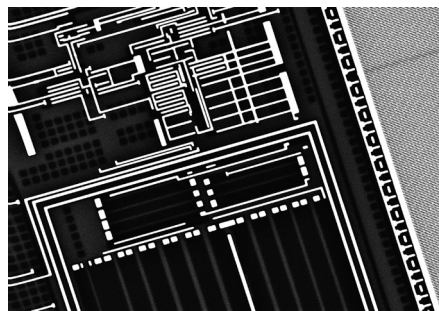


Fig. 9: Compositional contrast on semiconductor device (BSE).

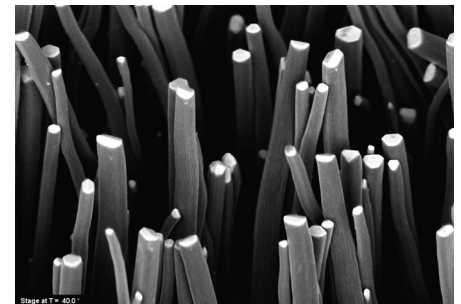


Fig. 10: Carbon-nanotubes with Ni-particles (SE/BSE mix).

with secondary and backscattered electrons at a voltage as low as 100V and working distances down to 1mm. Low voltage BSE imaging with the EsB detector allows for advanced metrology and suppresses charging effects on non-conducting samples (Fig. 8, 9 and 10). Application fields for the Ultra FESEM areas 'diverse as magnetic specimens, barrier layers in semiconductor devices, compositional imaging, particle analysis and immuno-gold labelling.

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justment in the range from 0 to minus 3000 volts enables real-time mixing and simultaneous observation of surface, voltage and material contrasts, without interfering with the primary beam.

The Ultra FESEM integrates all the latest developments of the Zeiss Gemini technology, enabling precise and clear simultaneous ultra high resolution imaging