

New Developments in GEMINI® FESEM Technology

H. Jaksch, J-P Vermeulen
 Carl Zeiss SMT Oberkochen, Germany
 vermeulen@smt.zeiss.com

Introduction

The Field Emission SEM was introduced to improve imaging resolution available with conventional SEMs with a tungsten source. Thermal assisted or Schottky Field Emission SEMs were introduced in the nineties by a number of companies as a stable source to overcome the beam instability of the cold FESEM introduced earlier. The GEMINI® based Field Emission SEM launched by ZEISS 12 years ago has been designed from the beginning as a high stability FESEM with a relatively large multi-ported chamber. The drive to develop GEMINI® technology was the need for a FESEM capable of ultra-high resolution performance over the entire accelerating voltage range that also possessed the flexibility needed for a wide range of analytical applications.

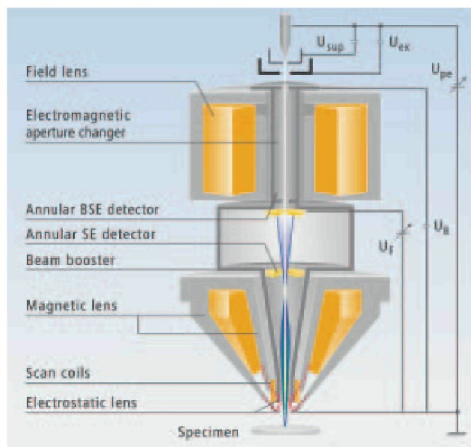


Fig. 1: Cross section of the GEMINI® electron optical column utilised in the ULTRA FESEM.

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

GEMINI® technology has been designed to 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
- Thermal assisted FE source – no flashing needed and gives stability for X-ray mapping and EBSD
- Depth of penetration of the electron beam into the specimen surface – deeper penetration yields 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 give better contrast and higher signal to noise ratio: In-column detectors to improve resolution

The GEMINI® column integrates a number of innovations 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. The name GEMINI® has been derived from Castor and Pollux,

the astronomical “twins” of Gemini, in this case the twin end lens and the electrons travelling down to the specimen and up to the detector.

GEMINI® FESEM Column Design

The Schottky FE source used in the GEMINI® column achieves a similar low energy spread compared to a cold field emission source, but with a much higher emission current and much higher

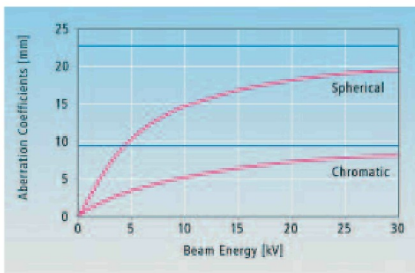


Fig. 2. GEMINI®’s decreasing spherical and chromatic aberrations with decreasing landing energy

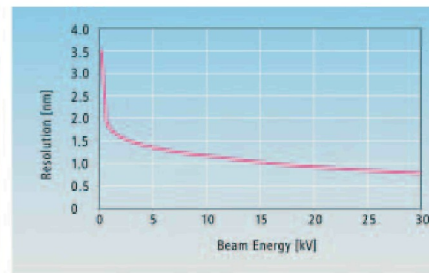


Fig.3. GEMINI®’s guaranteed resolution depending on landing energy.

beam stability. Regeneration of the beam tip (flashing) is not required. The GEMINI® column features the innovative integrated 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 sources.

Ultra low voltage imaging capabilities

One of the most important features of the GEMINI® column is the decreasing aberrations manifested with decreasing beam energy—assuring superb resolution even at ultra-low voltages, see fig. 2. The magnetic / electrostatic lens combination increases the incident beam aperture angle at the specimen, which improves both the signal to noise ratio and the resolution, see fig. 3. The GEMINI® lens is shaped to minimize the magnetic field at the specimen. Therefore, high resolution imaging of dia-, para-, or ferromagnetic materials is possible with very short working distances. The specimen is not emerged in a strong magnetic field like with other designs.

GEMINI® High Current Module

A further development of the GEMINI® column has resulted in the recently developed high current mode that allows for doubling the beam current compared to standard operating parameters. The high current in a smaller beam diameter gives a virtually parallel illumination at the sample, see fig.4, which greatly increases depth of focus, see fig 5a/b. The advantages for analytical applications like EBSD are that smaller crystals in the region of 20-50 nm can be detected and classified.

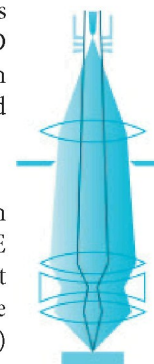


Fig. 4: Beam profile comparison, virtual parallel illumination with high current mode (narrow beam)

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, high-efficiency, 3rd generation In-lens detector boosts signal to noise ratio by a factor of 2-3, improves dynamic range, and does not suffer from ageing.

OLYMPUS

DIGITAL MICROSCOPY - at its best!

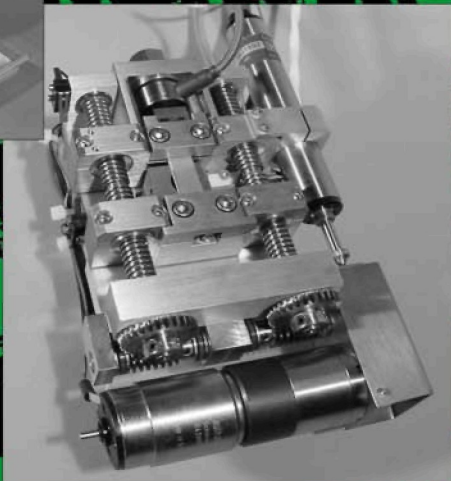


Olympus Industrial offers microscopes with outstanding optical performance and advanced features such as automation and digital imaging for industrial applications

Quality Assurance • Research • Failure Analysis

Call **OLYMPUS INDUSTRIAL** on **866 428 3697**

or visit our website: www.olympusmicroimaging.com/mt



CUSTOMIZING TO YOUR SPECIFIC NEEDS

Micro-manipulators, preparation materials, darkroom and general lab supplies, books, grids and apertures. Many items are manufactured in our machine shop, so customizing to your specific need is not a problem.

Some of the accessories and laboratory supplies we can supply are tweezers, tools, TEM CCD imaging systems, tensile testers, turbo evaporators, sputter coaters, substages, specimen holders, standards, carbon coaters, and more...



ERNEST F. FULLAM, INC.
Microscopy & Laboratory Supplies

900 Albany Shaker Road Latham NY 12110 - 1491
Tel: 518.785.5533 / Fax: 518.785.8647

sales@fullam.com
www.fullam.com

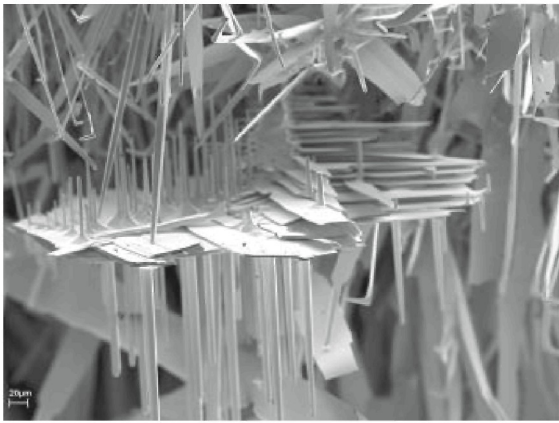


Fig. 5a: Normal imaging on high topography sample. The sample is 4mm high and was acquired at 4mm working distance and 1.2kV. Although the GEMINI® column is still superior to other systems under these conditions, the limited depth of field is noticeable.



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.

New GEMINI® based FESEM: ULTRA

The ULTRA FESEM, introduced last year, is based on the SUPRA™ series of FESEMs and features a second In-column detector enabling simultaneous detection of backscattered electrons (BSE) with 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, see fig. 6. The BSE pass the central aperture and are then projected on the EsB detector, see fig.7. To avoid any unwanted overlay with SE electrons, a filtering grid is installed in front of the EsB detector to repel any SE that may have passed through the In-lens aperture. Adjustment in the range from 0 to minus 3000 volts enables

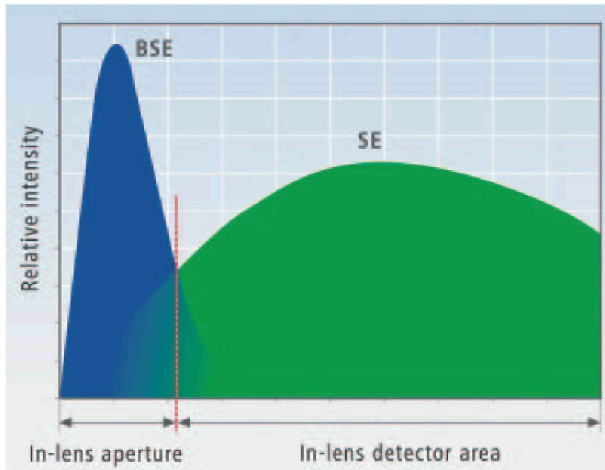


Fig. 6: Radial distribution of BSE and SE in the In-lens detector plane. Clearly visible is the separation of the electrons at the In-lens SE detector plane and the high detection efficiency of both detectors.

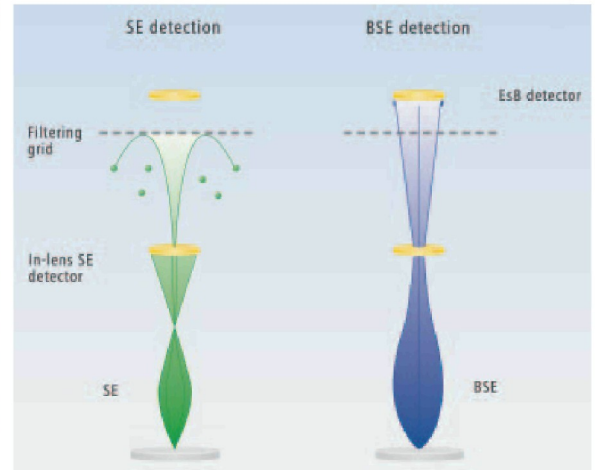


Fig. 7: The SEs (green) are projected onto the high efficiency In-lens detector and the BSEs (blue) are guided onto the integrated EsB detector.

specimens, barrier layers in semiconductor material, compositional imaging, particle analysis and immuno-gold labelling. ■

References:

Jaksch, H, Materials World, Oct. 1996
 Gnauck, P, SEM 2000, Goeteborg 17 – 19 Oct 2000
 Steigerwald, M.D.G., Imaging & Microscopy 4.03 (2003) 46

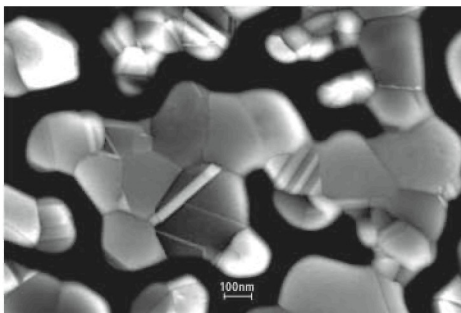


Fig. 8: Evaporated Au particles on carbon with clearly visible twins (BSE)

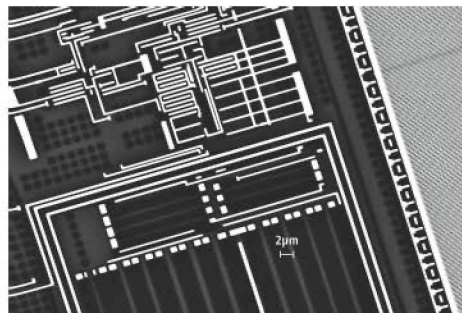


Fig. 9: Compositional contrast on semiconductor device (BSE)

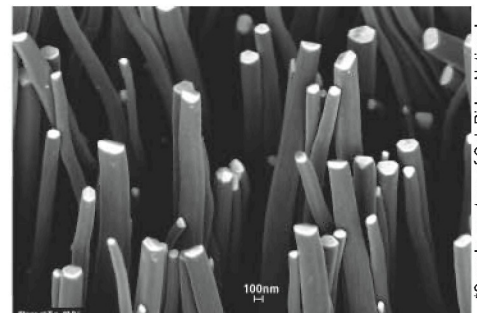


Fig. 10: Carbon-Nanotubes with Ni-particles (SE/BSE mix)*

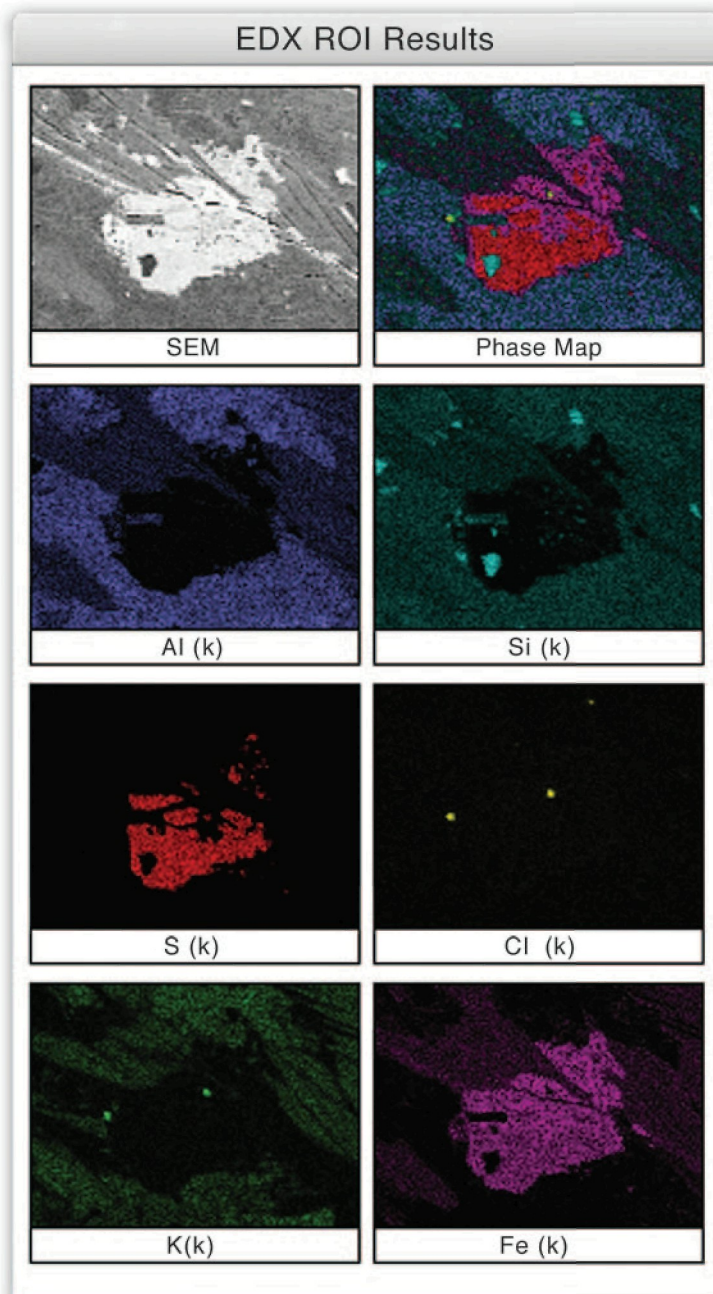
*Sample courtesy of Oak Ridge National Labs and Cornell Nanoscale Facility.

Don't want to miss elements that
may be hiding in your sample?

Maximum Pixel Spectrum



EDX and Digital Imaging Systems



joins 4pi Revolution®

Contact 4pi to ask how its Maximum Pixel Spectrum and Dynamic Element Mapping can benefit your microanalysis results.

4pi Analysis, Inc. • 919-489-1757 • info@4pi.com • www.4pi.com