A Novel GEMINI® STEM Detector System

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Introduction

By using a scanning transmission electron microscopy (STEM) detector, the information limit for the GEMINI® FESEMs can be extended beyond the nanometer range. A resolution of 0.8 nm at 30kV is now readily attainable and gives additional nanoscale information compared to conventional SEM detectors. The resolving power of the combined FESEM/STEM can be used to save processing time on TEM systems and enables high sample throughput for quality assurance applications and standard type measurements. The transmission mode of the FESEM has the advantages of avoiding chromatic aberration, allowing for a larger aperture so that higher transmission, signal–to-noise ratio and contrast enhancement due to the lower electron energy (10 - 30kV) can be obtained. The electron range in Aluminium for instance is approx. 5 μm @ 30 kV against approx 45 μm for 100 kV, hence more contrast generating scatter interaction takes place at the lower voltage of 30 kV.

The bright field (BF) imaging mode in STEM originates from the non-scattered or near-axis scattered electrons. The dark field (DF) imaging mode originates from the more widely scattered electrons.

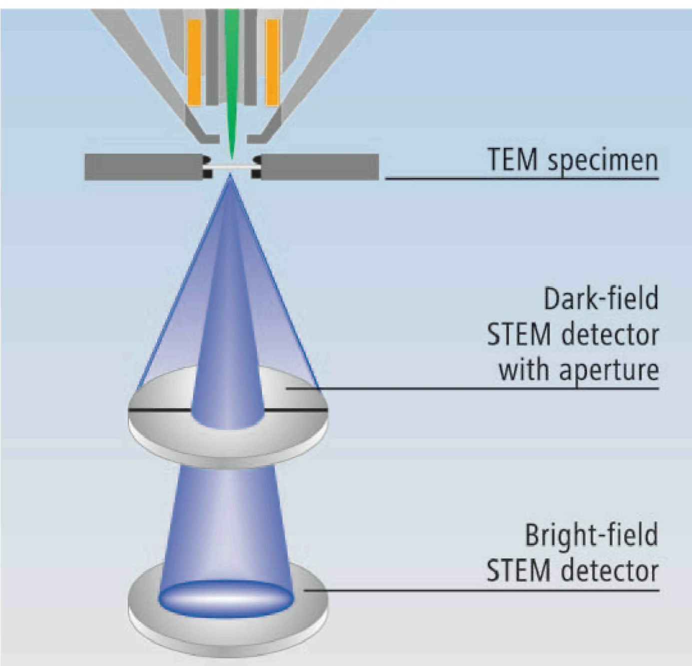

Fig. 1: Multi-mode STEM detector diodes.

The classic STEM detector, used since the SEM was introduced, consists of a single electron detector area positioned under a replica or a thin, electron transparent section. Another STEM detection system used a conversion plate to produce a converted TE/SE signal. The signals provided were: BF (Bright Field), DF (Dark Field) or most likely the unwanted sum of both signals, which could lead to a loss of information. The newly developed multi-mode STEM detection system enables simultaneous separate BF, DF and orientated DF (ODF) signals, without any need for realignment during imaging, see Figure.1.

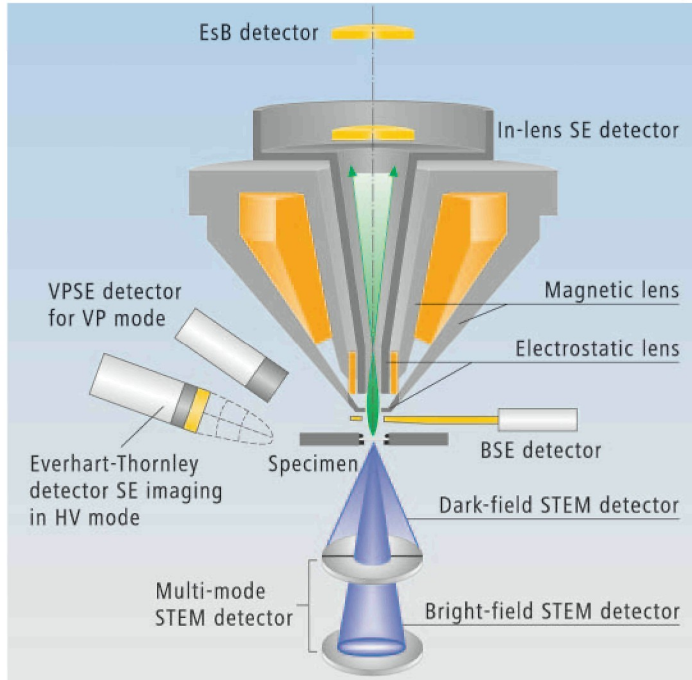

Fig. 2: Detector systems for the ZEISS GEMINI® FESEM.

Gemini® Multi-mode STEM Detector

The GEMINI® multi-mode STEM detection system is comprised of two parallel, long-life diode-detector surfaces. The top detector (DF) has been divided into specific areas to allow orientated DF imaging and forms the aperture for the BF signals which are detected by the lower detector as displayed in Figure 2. The arrangement of the top detector for the BF signal comprises an aperture for separation of the BF and DF signals. The transmission electron microscopy (TEM) specimens are mounted on a carousel-type TEM grid holder which can hold up to 6 specimens. As shown in Figure 3, the multi-mode STEM detector is mounted on a completely retractable assembly fitted with a high-precision adjustment mechanism so that optimum alignment can be obtained, and can be used in combination with all other GEMINI® detectors, see Figure 4. The combination of the resolving power of the FESEM and the separate BF and DF signal detection capabilities of the multi-mode STEM detection system could replace a classic TEM for a variety of applications. Even non-conducting specimens, non-stained

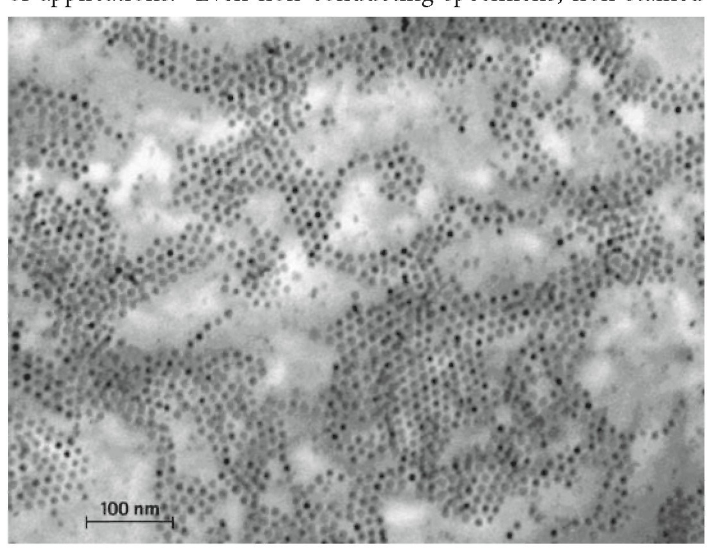

Fig. 3: Combined BF + ODF image of magnetic cobalt nano particles (27kV)

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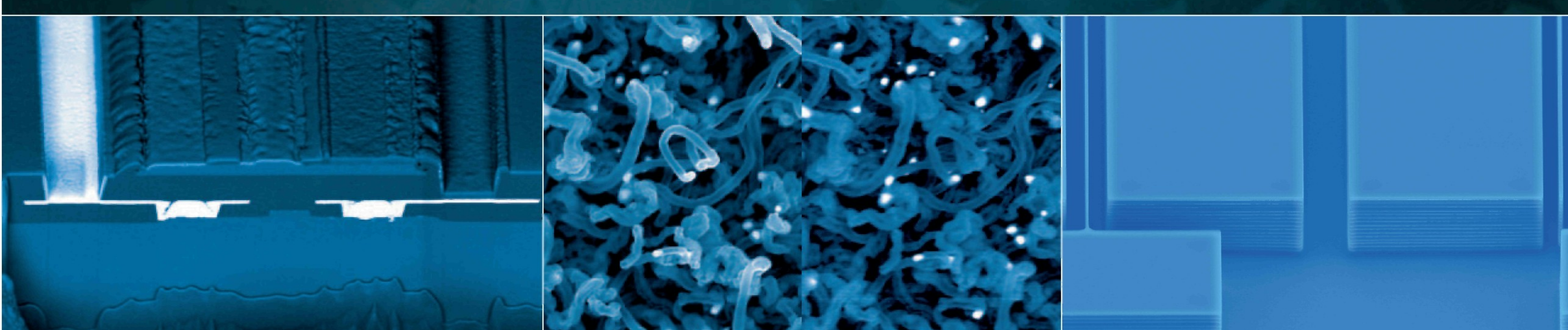

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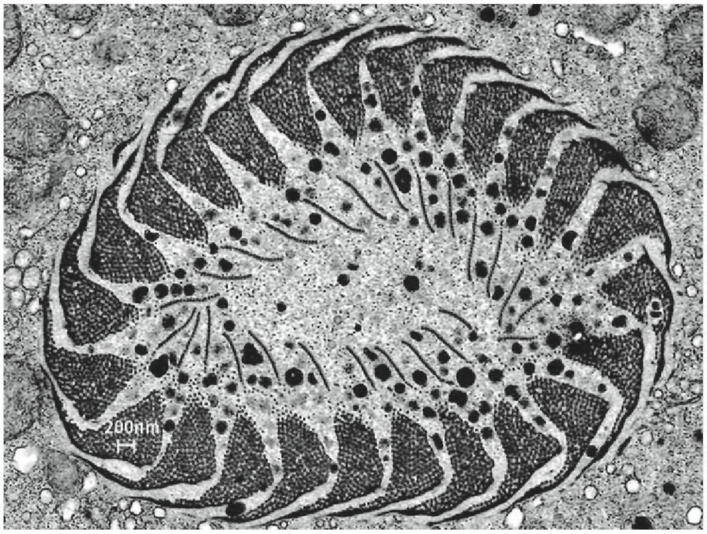

Fig. 4: Cross section of stained ciliate (30kV).

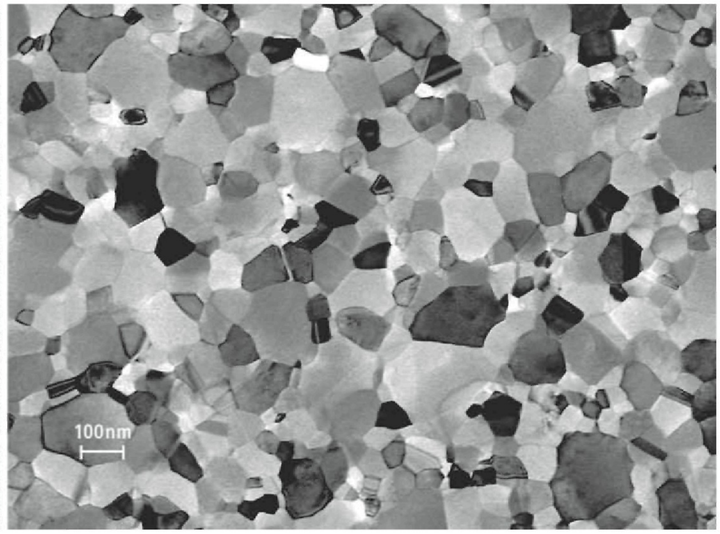

Fig. 5: Combined DF + BF signal of an aluminium sample (30kV).

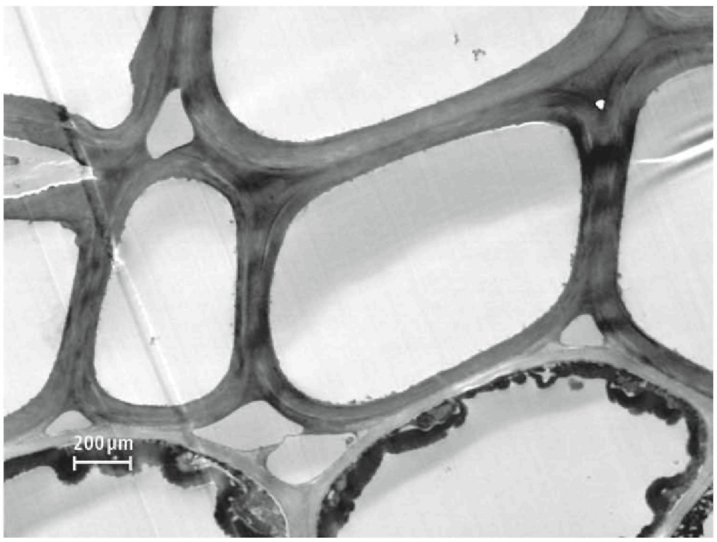

Fig. 6: Cross section of unstained wood (30kV).

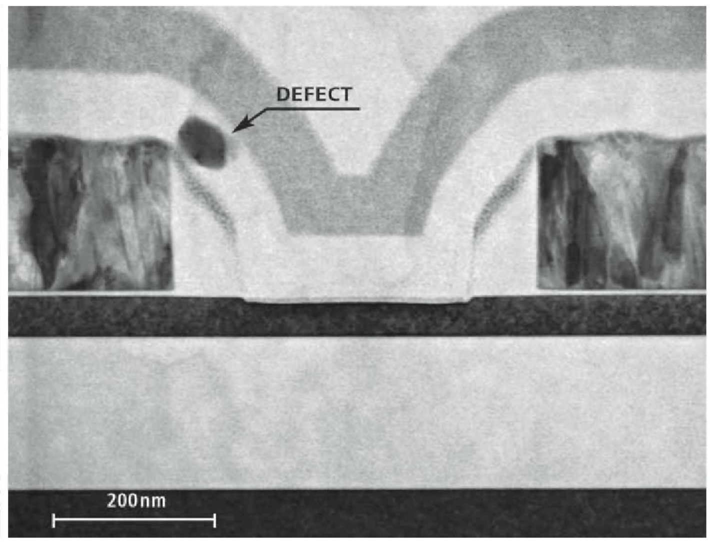

Fig. 7: A BF image of semiconductor TEM lamella prepared with the ZEISS CrossBeam®. A very small defect in a layer was exactly hit in the centre and is clearly visible.

organic material or ceramics, can be imaged in VP mode without any charging effects as presented in Fig. 6.

Signal Enhancement

Compared to conventional TEM (80 – 300 kV) images, those obtained with the multi-mode STEM detection system show improved signal-to-noise ratio and enhanced contrast with comparable resolution. This is due to significantly lower electron beam energies used in the FESEM, which result in reduced excitation volume and increased electron scattering cross-sections at lower accelerating voltages (10 – 30 kV). Thus, subtle contrast mechanisms (Fig. 5, 6, 7) may be explored.

The multi-mode STEM detector enables pure BF or DF imaging to achieve optimum contrast and rich imaging details of even unstained thin sections of biological materials. Moreover, the small excitation volume in thin sections results in a 10x improvement of the lateral resolution of EDX analysis, and accurate analysis of particles down to 30 nm is now achievable. Due to parallel detector surfaces and the division of the DF detector, the multi-mode STEM detection system allows for six distinctive imaging modes: BF, DF, BF+DF, BF-DF, OD1+ODF2 and ODF1 - ODF2.

Typical fields where STEM operation in a SEM maybe beneficial include:

- Materials Analysis (polymer, ceramics, nanoparticles, grain boundaries),
- Life science (histology, pathology),
- Semiconductors (failure analysis, FIB lamellas).

Another new application area for the multi-mode STEM detector is in the CrossBeam® combined FIB / FESEM system. The CrossBeam® enables site specific TEM lamella milling directly out of bulk material with the focussed ion beam (FIB) system with permanent simultaneous high resolution imaging with the FESEM. The produced lamella can be imaged and analysed in-situ with the STEM detector and an example is shown in Fig. 7. ■

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