"Ethos NX5000" High-Performance FIB-SEM

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1. Introduction

Hitachi High-Technologies Corporation has developed the Ethos NX5000 high-performance FIB(*1)-SEM(*2), which combines a high-intensity cold-cathode field emission electron gun technology with a newly developed magnetic/electrostatic compound lens (or *dual-mode lens*).

FIB-SEM instruments incorporate a FIB column for sample processing and a SEM column for high-magnification observation in a single specimen chamber. A two column system allows for fine structure and compositional observation of specific regions along the specimen plane as well as subsurface regions of interest. FIB-SEM systems are used in a wide variety of application fields, such as semiconductors, nanotechnology, materials science, medicine, and biology, for cross-sectional observation and analysis of samples, as well as preparation of thin-film TEM(*3) samples. In recent years, FIB-SEM instruments play an important role in the fabrication of high-quality thin-film TEM samples, which have proven essential for the analysis of fine structure and composition of advanced devices, including high-performance nano-materials created in research and development laboratories.

The key design concepts of the Ethos NX5000 are high-resolution observation, preparation of high-quality TEM samples, and flexibility. To this end, the instrument allows high-resolution SEM at low accelerating voltages and incorporates ACE(*4) technology—methods for reducing curtaining effect(*5) which may occur in cross-sectional processing via FIB. ACE technology is essential to minimize FIB induced damage and enable high-quality thin-film TEM prepared samples with absolute uniformity. The newly developed large-volume sample chamber can be configured with optional ports for a variety of analytical options—such as EDS(*6) or EBSD(*7)—and the instrument is equipped with a newly developed large sample stage allowing observation and processing of 150 mm diameter samples in their entirety. This allows the instrument to offer compound analysis of a wide variety of samples, including not only cutting-edge semiconductor devices but also samples ranging from biological tissue to steel or other magnetic materials.

In this article, we discuss the key strengths of the Ethos NX5000 high-performance FIB-SEM.

Fig. 1 Ethos NX5000 high-performance FIB-SEM

Table 1: Main specifications

SEM optical system	
Power supply	Cold-cathode field emission gun
Accelerating voltage	0.1–30 kV
Resolution	1.5 nm (1 kV), 0.7 nm (15 kV) (HR mode)
FIB optical system	
Accelerating voltage	0.5–30 kV
Maximum beam current	100 nA
Resolution	4.0 nm (30 kV)
Stage	
Stroke	X: 0–155 mm, Y: 0–155 mm, Z: 0–16.5 mm, T: –10–59°, R: 360° Note: Stroke may be restricted by the sample holder.
Sample size	150 mm diameter max

2. New Electron-Beam Optical System

The key design concept behind the new electron-beam optical system are high resolution and a wide variety of configurations for observation. To achieve high resolution, the instrument is equipped with a high-intensity cold-cathode field emission electron gun and a newly developed dual-mode lens system. This dual-mode lens offers both single-pole (HR) and out-lens (FF) functionality. Specimens may be observed at high resolution in HR mode, while FF mode allows real-time monitoring during sample processing by FIB.

In addition, multiple detection signals such as, SE (U), BSE (U), and BSE (L) detectors are equipped inside of the SEM column. Moreover, the sample chamber is equipped with an additional in-chamber SE (L) detector, from which all signals can be obtained simultaneously for efficient image acquisition. This allows simultaneous observation of morphology contrast via secondary electrons and composition contrast via backscattered electrons.

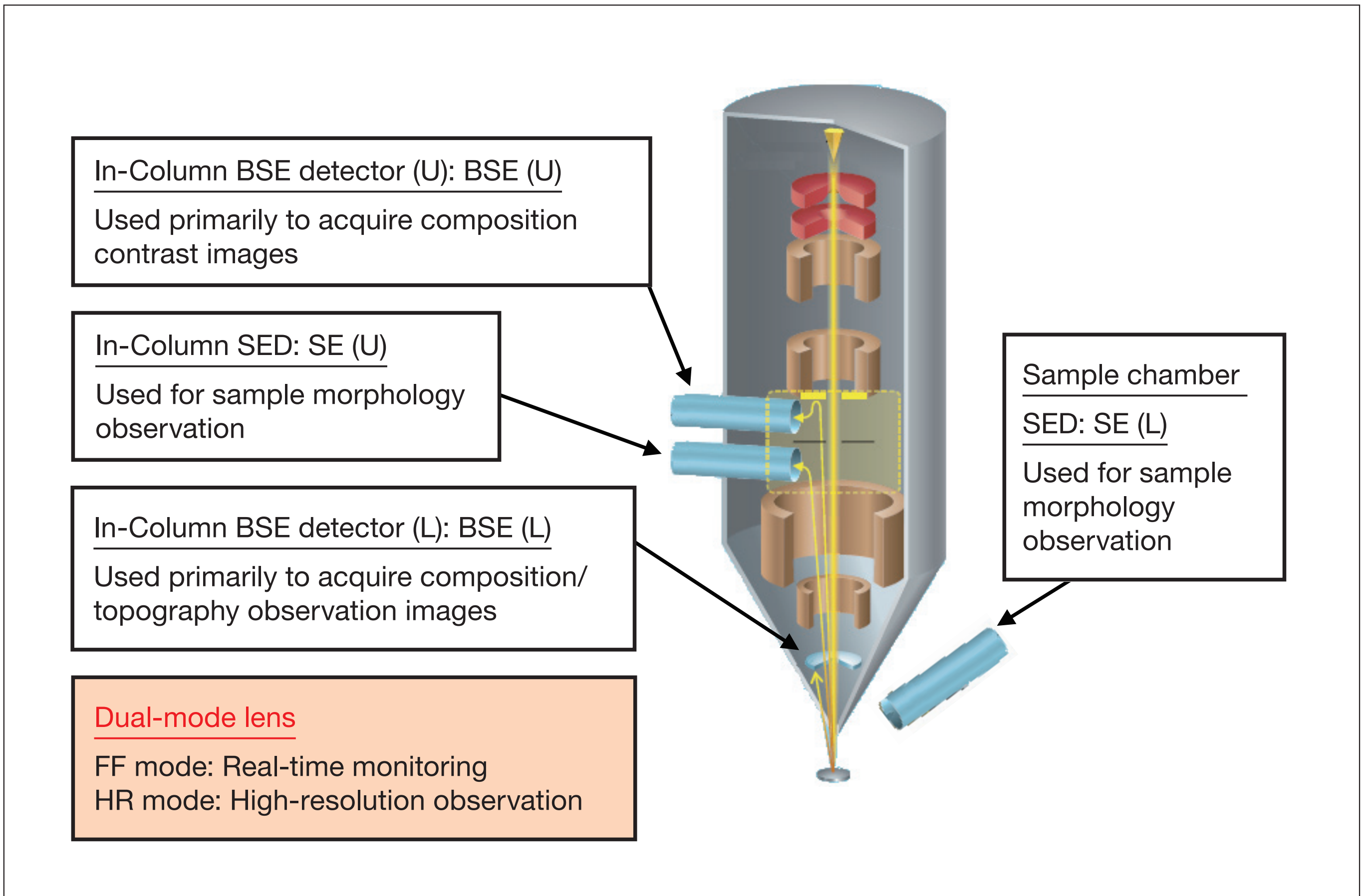

Fig. 2 Schematic depiction of new electron-beam optical system

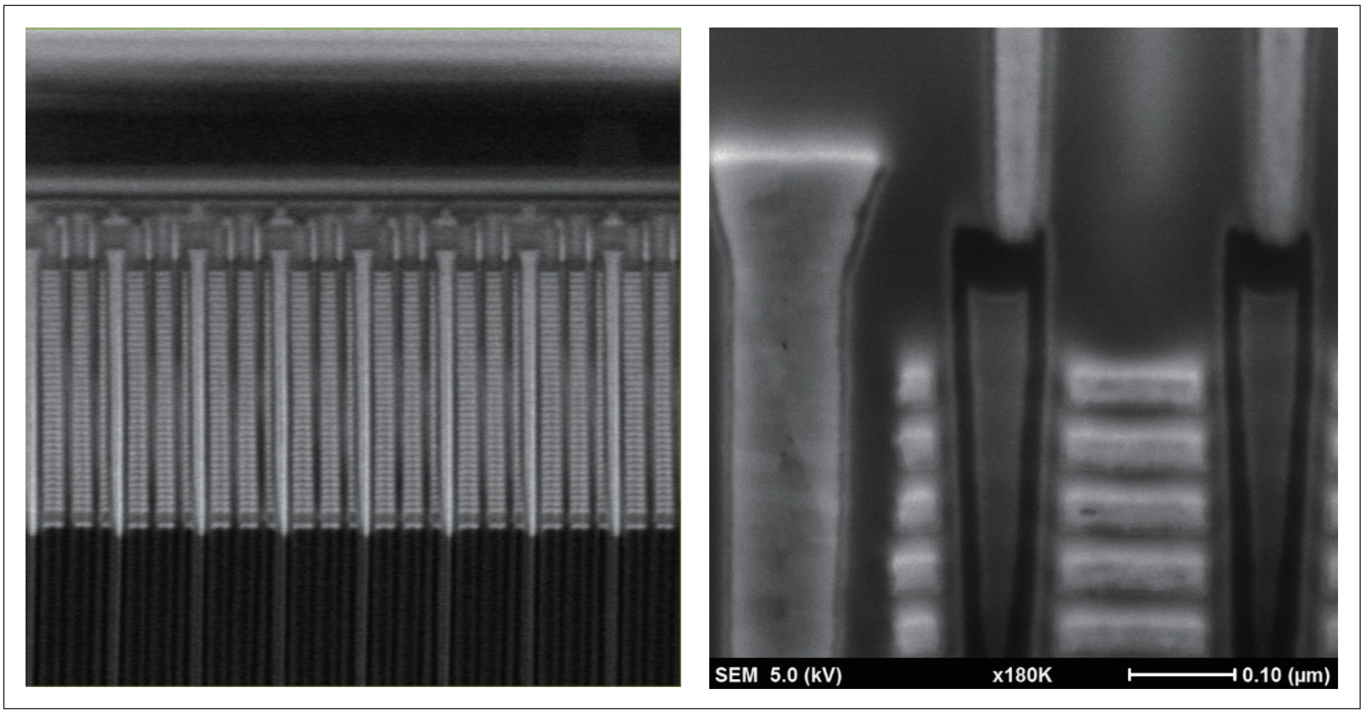

Fig. 3 Left: Real-time monitoring via FF mode (Acc: 2 kV, field of view: 6 μm)
Right: High-resolution observation via HR mode (Acc: 5 kV, field of view: 0.6 μm)
Sample: Commercially available 3D-NAND flash memory

3. Fabricating High-Quality TEM Samples with Triple Beam and ACE Technology

The Ethos NX5000 is equipped with several features to support the fabrication of high-quality TEM samples: Triple Beam and ACE technology. These features have earned high praise from TEM sample-fabrication laboratories in many fields of science and engineering.

Triple Beam is a unique instrument configuration developed by Hitachi High-Technologies in which FIB induced damage layers during FIB processing are eliminated by etching with a low-acceleration argon / xenon beam (ArIB / XeIB). In the Triple Beam configuration, three beams—FIB, EB, and ArIB (XeIB)—coincide at a single point on the sample[1), allowing the results of FIB and ArIB (XeIB) processing to be observed via in-situ SEM. This yields a major improvement in the operational efficiency of TEM sample damage elimination.

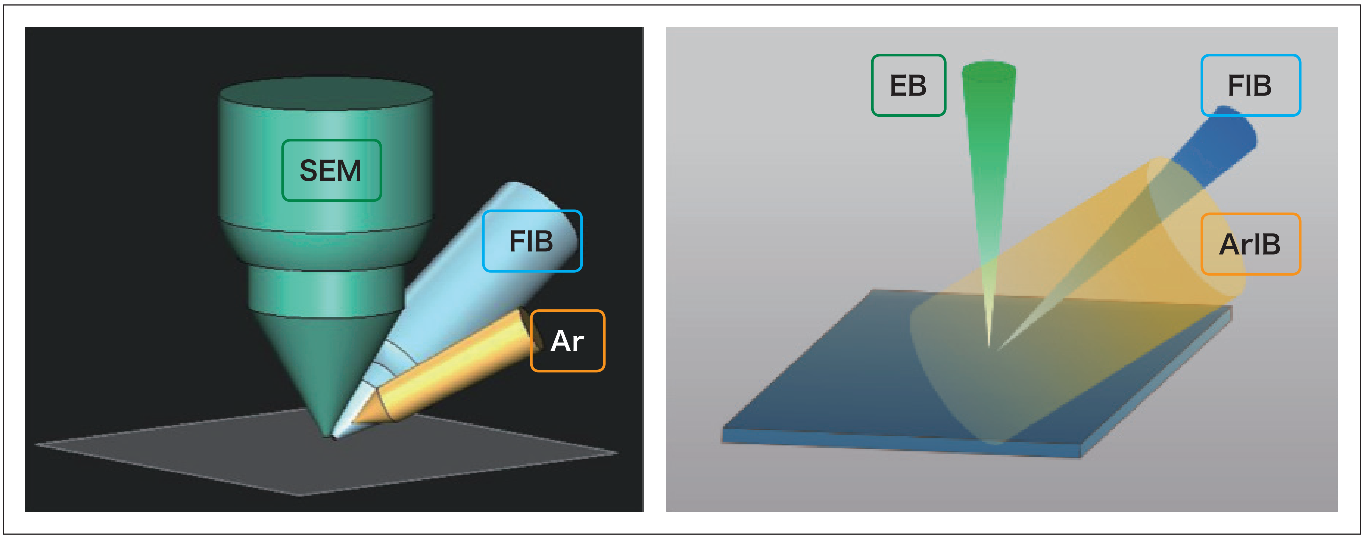

Fig. 4 Schematic illustration of Triple Beam

ACE technology is a set of techniques for reducing curtaining effects arising in sample cross sections during the process of TEM sample preparation. When the interior of a sample contains many materials with different etching rates, striations in the sample cross section can appear as the sample is thinned. Phenomena of this sort are known as curtaining effects. The accumulation of striations in sample observation regions due to curtaining effects results in degradation of TEM image quality. To address this problem, the Ethos NX5000 is equipped with technology to control the orientation[2)] of the sample via rotational-axis microsampling, which is one component of ACE technology. The use of this technology allows orientation control for thin-film samples fixed to a TEM mesh. This enables the direction of FIB irradiation of the sample to be controlled, reducing the impact of curtaining effects.

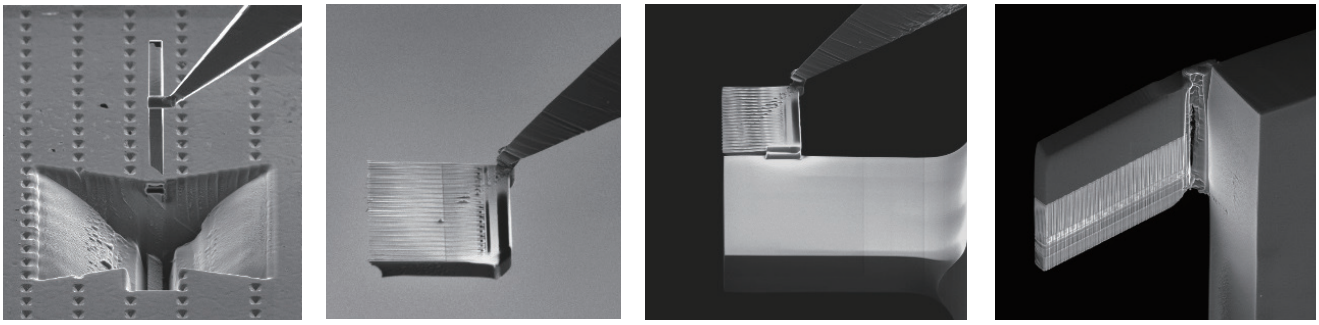

Fig. 5 Illustration of orientation control of thin-film samples via rotational-axis microsampling

4. New Platform

A new and highly extendable design platform to enable the Ethos NX5000 to perform a wide variety of SEM analyses. In the new platform, the SEM column is configured vertically above the sample chamber, allowing for the placement of 13 ports. This allows the instrument to be equipped with options for additional types of SEM analyses, including EDS, EBSD, retractable CL, retractable STEM, and retractable BSD.

In addition, the newly developed 5-axis 150 mm stage not only allows observation of wafers up to 6 inches in size in their entirety, but also supports a wide range of sample sizes through the use of various types of sample holder.

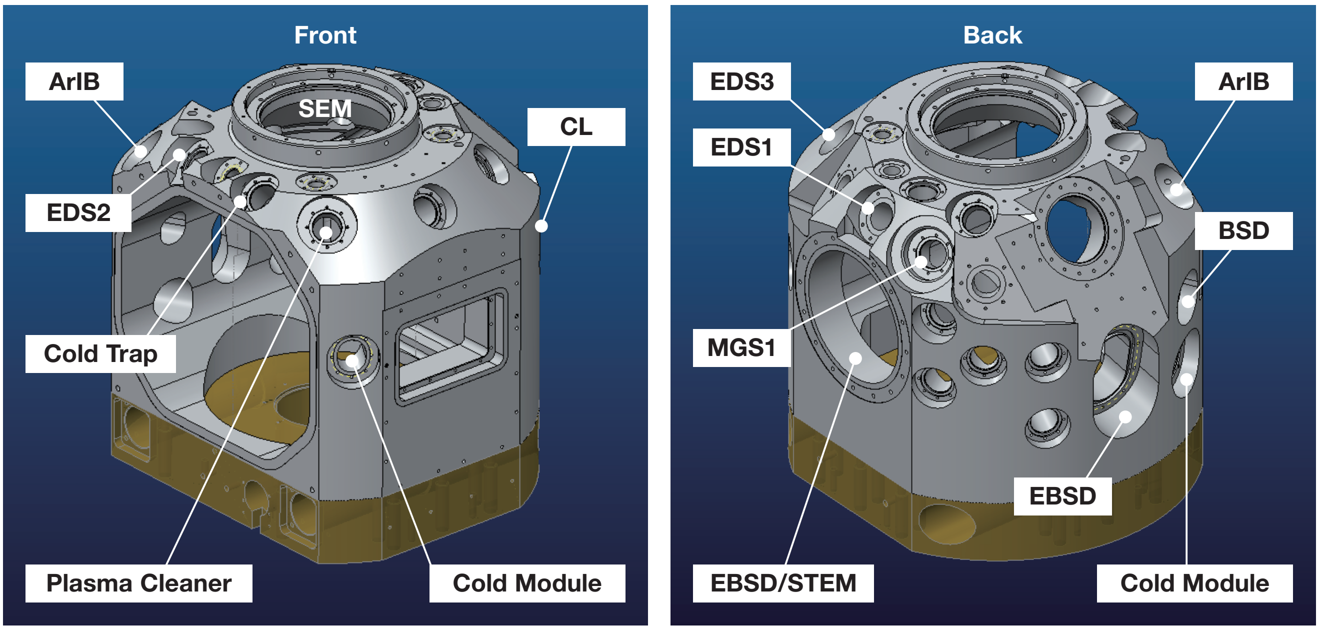

Fig. 6 Port layout of Ethos NX5000 sample chamber

5. Conclusions

The newly developed Ethos NX5000, an instrument jointly developed by Hitachi High-Technologies Corporation and Hitachi High-Tech Science Corporation, is a successor to the NX2000 (released September 2014) and NX9000 (released June 2015) instruments.

Going forward, our two firms will continue to combine our long-cultivated traditions of SEM and FIB expertise to create instruments that enable research and development at the frontiers of science and engineering.

(*1) FIB: Focused Ion Beam
(*2) SEM: Scanning Electron Microscope
(*3) TEM: Transmission Electron Microscope
(*4) ACE: Anti Curtaining Effect
(*5) Curtaining effect: Surface roughness arising during FIB processing caused by variations in processing rate due to sample structure or material composition.
(*6) EDS: Energy Dispersive X-ray Spectrometer
(*7) EBSD: Electron Backscatter Diffraction

References

1) H. Takahashi *et al*., The 63rd Annual Meeting of The Japanese Society of Microscopy (2007).

2) K. Kondo *et al*., The 28th Annual LSI Testing Symposium preprint (2008).

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