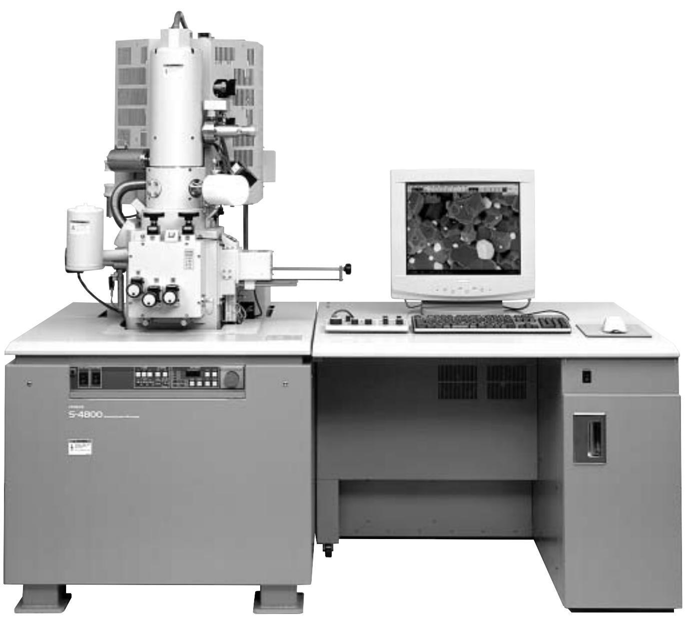
SUBJECT: DARK FIELD STEM FUNCTION OF THE S-4800 FE-SEM AND SOME APPLICATIONS

INSTRUMENT: THE S-4800 FIELD EMISSION SCANNING ELECTRON MICROSCOPE
THE FB-2100 FOCUSED ION BEAM SYSTEM

CONTENTS



A general view of the S-4800 FE-SEM

1. INTRODUCTION

The S-4800 Field Emission Scanning Electron Microscope (FE-SEM) has been developed with a snorkel objective lens in response to user requirements for better imaging resolution, acquisition of specimen information suitable for multiple evaluation purpose and minimized specimen damage. The S-4800 has been utilized in leading edge technologies such as semiconductors and advanced materials. SEM applications are not limited to surface topography of specimens, but SEMs can also be used for observation of thinned specimens and inner structures of fine particles such as carbon nanotubes. For observation of inner structures, a technique called STEM (Scanning Transmission Electron Microscopy) is employed. It utilizes electrons which have transmitted through the specimen. Conventional STEM techniques with SEMs using out-lenses or snorkel lenses have used electrons which have transmitted through the specimen as shown in Fig. 1. This imaging technique is generally called bright field STEM. Transmitted electrons include not only bright field signals but also scattered electrons generated in the specimen. The imaging technique using these scattered electrons is called dark field STEM. In the dark field image, Z-contrast which reflect compositions in the specimen is made available.

Here in this Technical Data, we introduce a new dark field STEM function which is available as an option for the S-4800. We also introduce some applications of the dark field STEM function.

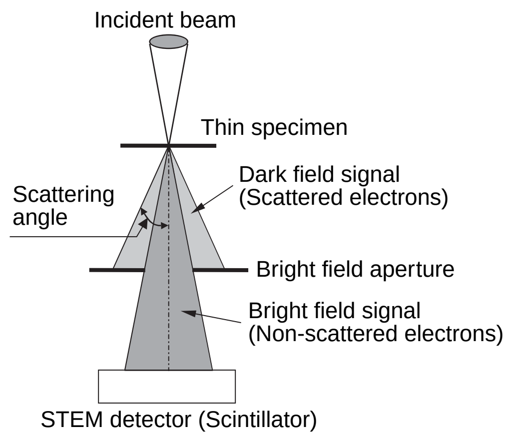


Fig. 1 Conventional STEM signal detection

2. DARK FIELD STEM FUNCTION

The dark field STEM function uses an electrode which converts scattered electrons into secondary electrons as shown in Fig. 2. The dark field signal is detected through secondary electrons. Since this function operates at a short working distance (WD) of 10 mm or smaller, secondary electrons generated from the specimen are pulled up by the magnetic field of the objective lens and detected by the Upper SE detector. The Lower SE detector detects dark field signals only which are converted by the secondary electron conversion electrode built into the specimen holder. By mounting the conventional bright field STEM detector (available as an option), simultaneous detection of both the bright and dark field signals which have transmitted through the secondary electron conversion electrode is possible. The S-4800 allows observation of the top most surface (SE) of the specimen, inner crystal information (bright field STEM), and compositional information (dark field STEM) of the same specimen area. This design permits evaluation of the specimen with multiple signals and different points of view.

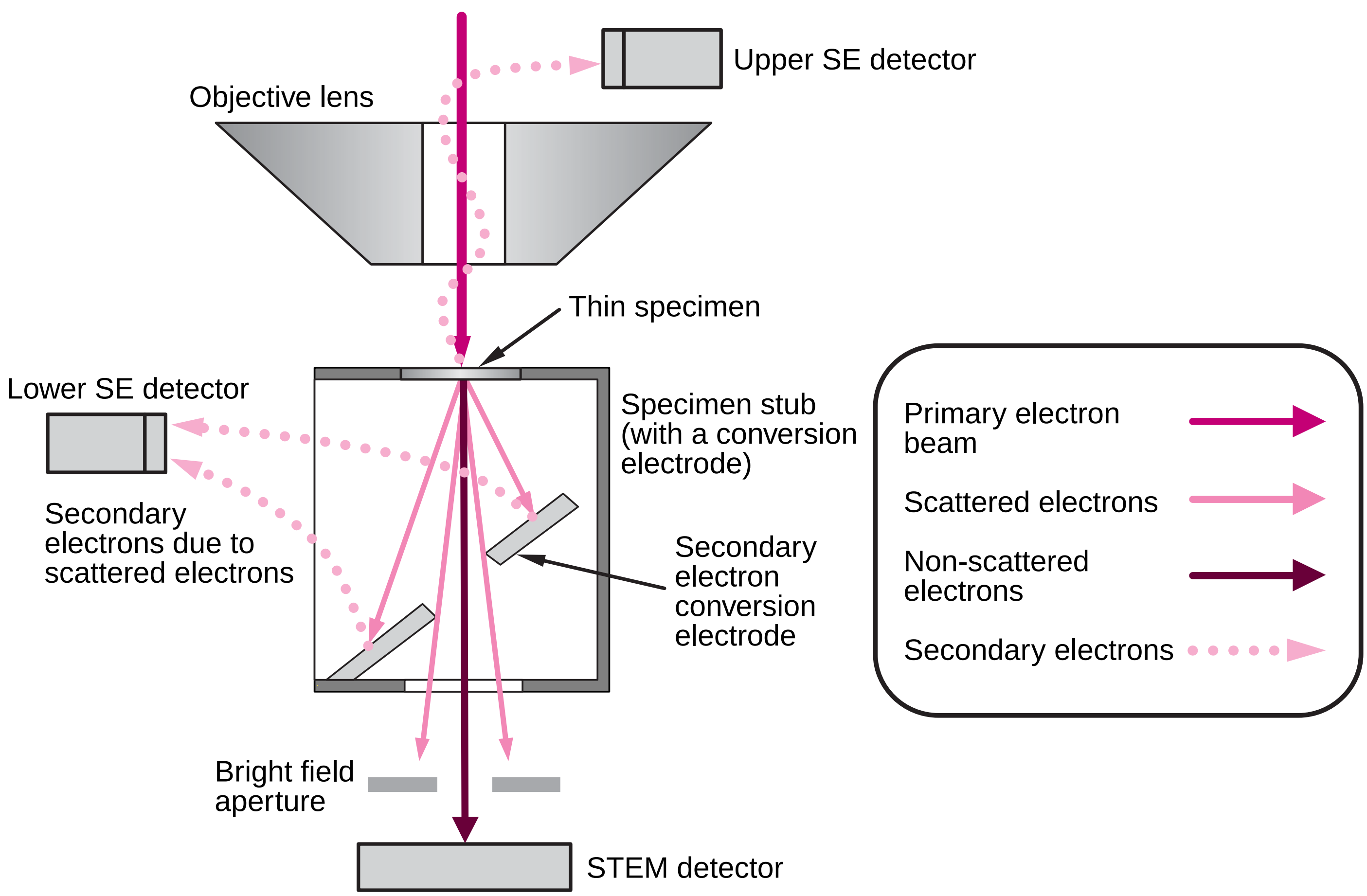
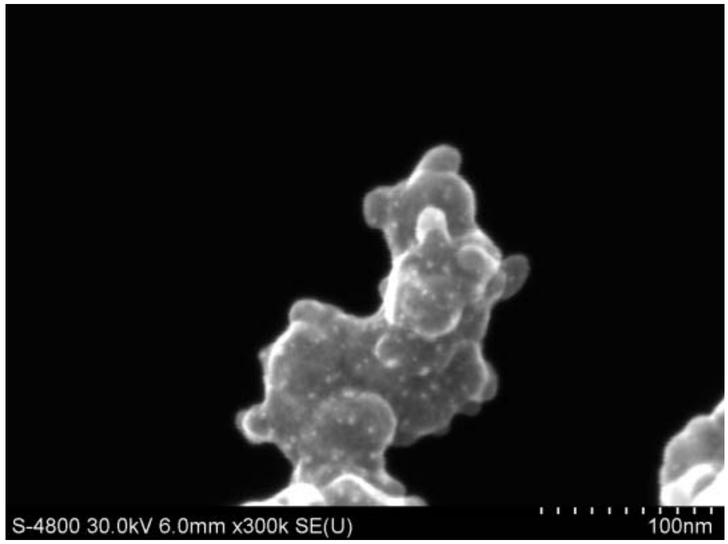


Fig. 2 A system layout for Dark Field STEM

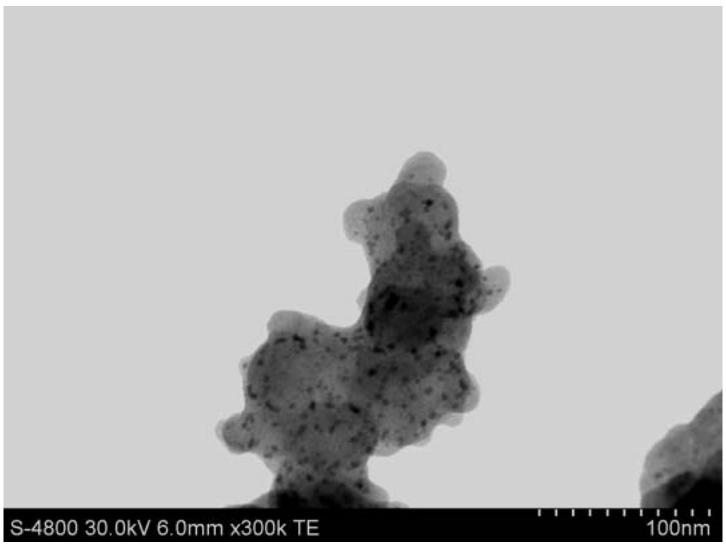
3. APPLICATIONS IN MATERIALS SCIENCE

3.1 Observation of platinum particle catalyzer

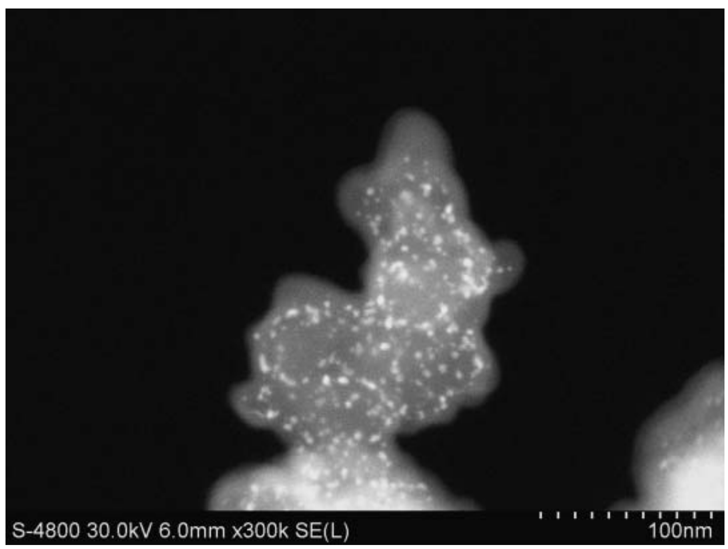
Fig. 3 shows a set of images recorded in SE, bright field STEM, and dark field STEM recorded from the same field of view on platinum particles in catalysts. The SE image (a) shows junctions of carbon particles and platinum particles attached on the surface. The bright field STEM image (b) shows platinum particles on the surface as black particles. The dark field STEM image (c) shows platinum particles as white dots displaying the particle dispersion very well.



(a) SE image



(b) Bright field STEM image



(b) Dark field STEM image

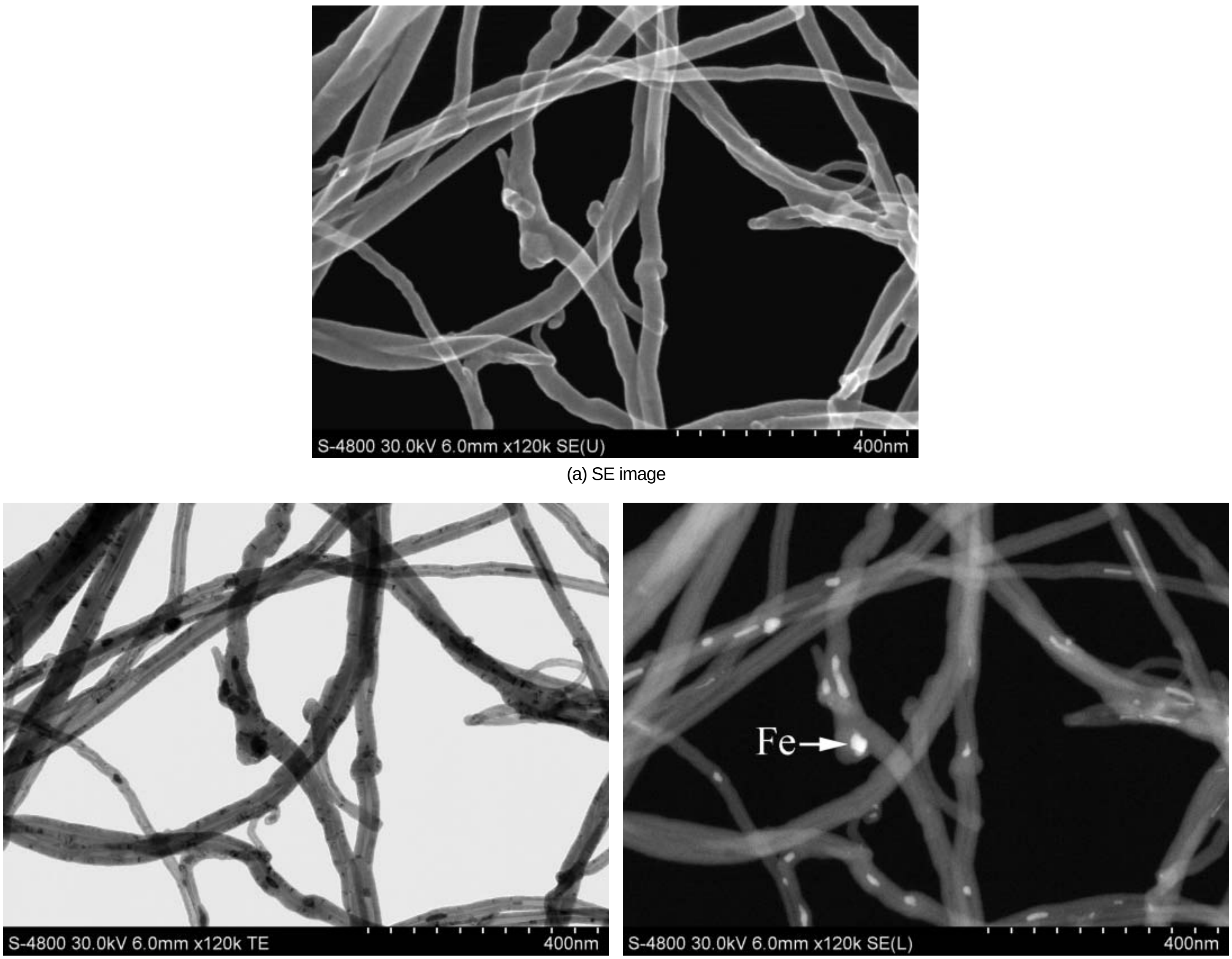
Fig. 3 Observation of platinum particles in catalyst

3.2 Observation of carbon nanotubes

Fig. 4 shows the same field of view on a carbon nanotube specimen recorded in SE, bright field STEM and dark field STEM images. The SE image (a) shows surface and overlapping conditions of the nanotubes. The bright field STEM image (b) shows external and internal diameters of the tube clearly. The dark field STEM image (c) shows iron, the internal catalyst composition. The dark field STEM image also allows evaluation of sizes and localizations of compositions.

3.3 Observation of toners

Fig. 5 shows toner particles recorded in SE, bright field STEM and dark field STEM images in the same field of view. The toner particles were protected by W-deposition using the FIB system, FB-2100. They were thinned to an approximate diameter of 150 nm . One of the evaluation criteria of this specimen (cyanogen toner) is the dispersion characteristics of particles within the toner, specifically copper contents. The SE image (a) shows surface topography of the toner particles identifying discrete voids in the toner however not revealing information about the copper particles. The bright field STEM images (b) and (d) show copper particles and voids in dark and bright contrast respectively. The dark field STEM images (c) and (e) show copper particles and voids in bright and dark contrast respectively. The dark field imaging technique is the preferred method as it shows the dispersion conditions of the copper clearly. The copper particle (circled) which is at the back of a void has been recorded clearer than in the bright field STEM image.

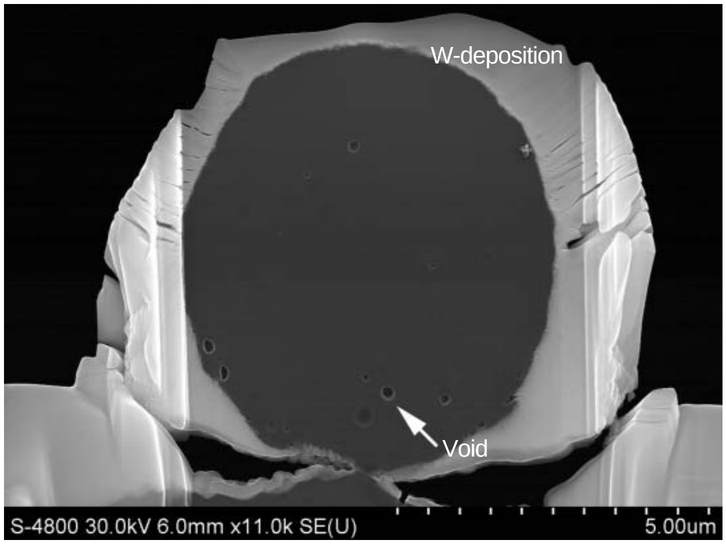


(a) SE image

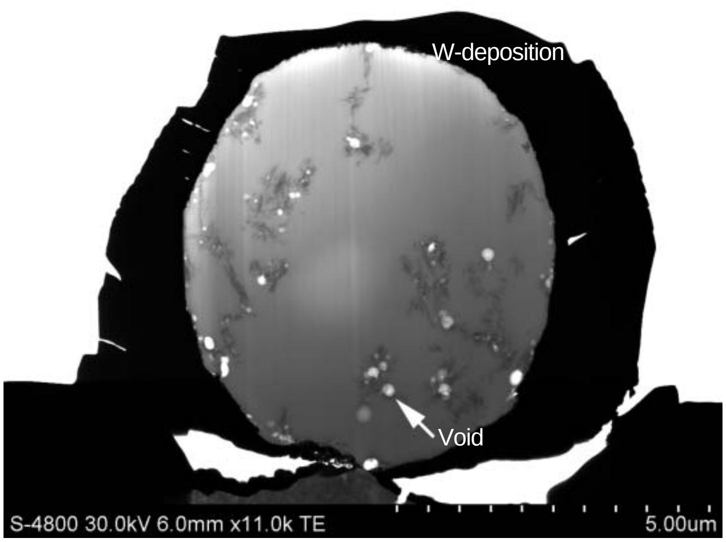
(b) Bright field STEM image

(b) Dark field STEM image

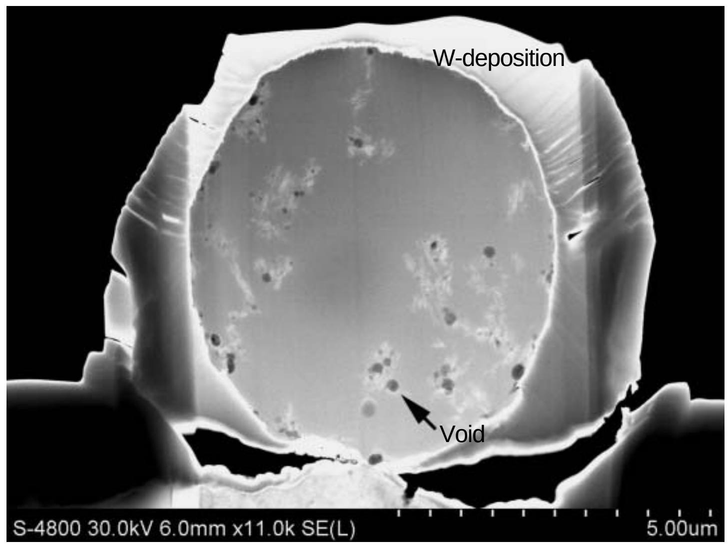
Fig. 4 Observation of carbon nanotubes



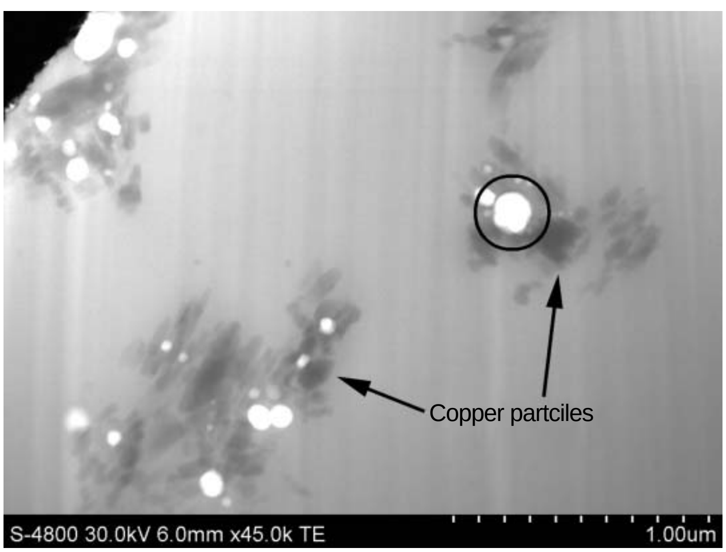
(a) SE image



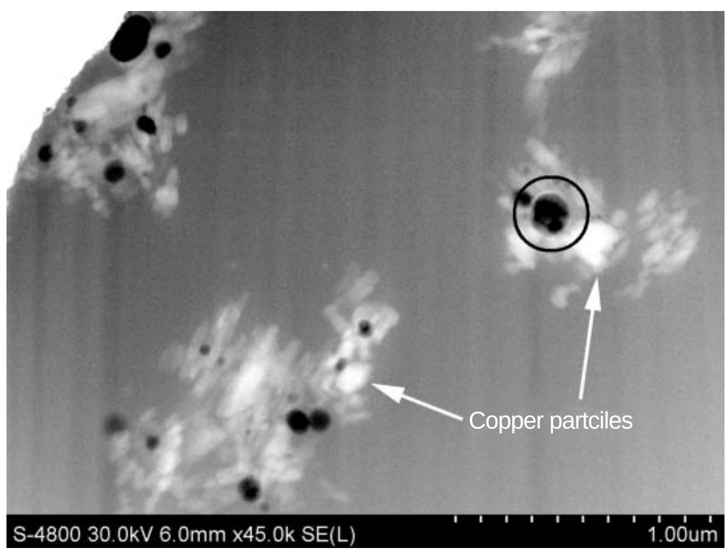
(b) Bright field STEM image



(c) Dark field STEM image



(d) Bright field STEM image



(e) Dark field STEM image

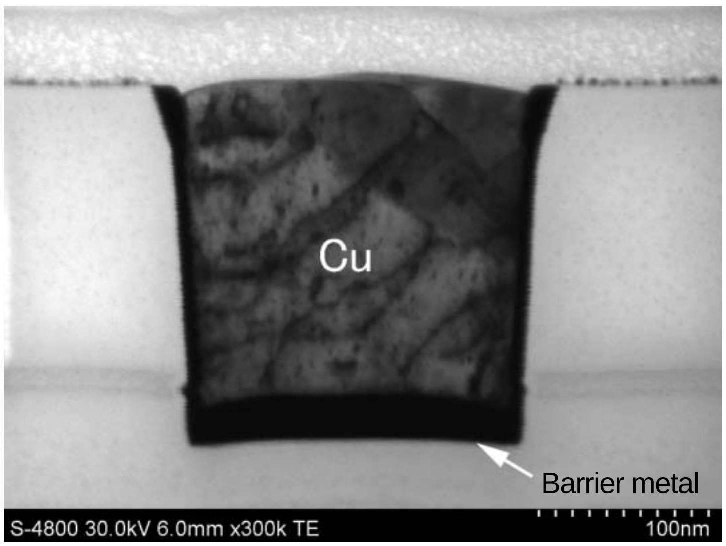
Fig. 5 Observation of toner particles

4. APPLICATIONS IN SEMICONDUCTORS

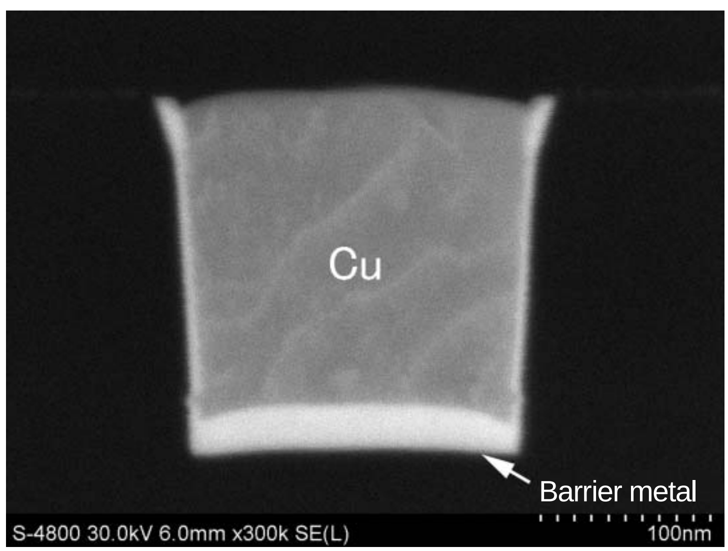
4.1 Observation of copper wiring

Fig. 6 shows a part of copper wiring recorded in bright field STEM and dark field STEM images. The specimen has been thinned to a thickness of about 100 nm using the FIB system, FB-2100. The bright field STEM image (a) shows the Ta-barrier metal as dark contrast and the copper wiring grains very clearly.

The dark field STEM image (b) shows the Ta-barrier metal bright and clear. When compared with the bright field STEM image, thickness measurement of coverage conditions of the barrier metal, side and bottom areas are easier to perform with accuracy. In this case the ability to collect both bright field and dark field images provides a complete evaluation of the copper wiring structure.



(a) Bright field STEM image

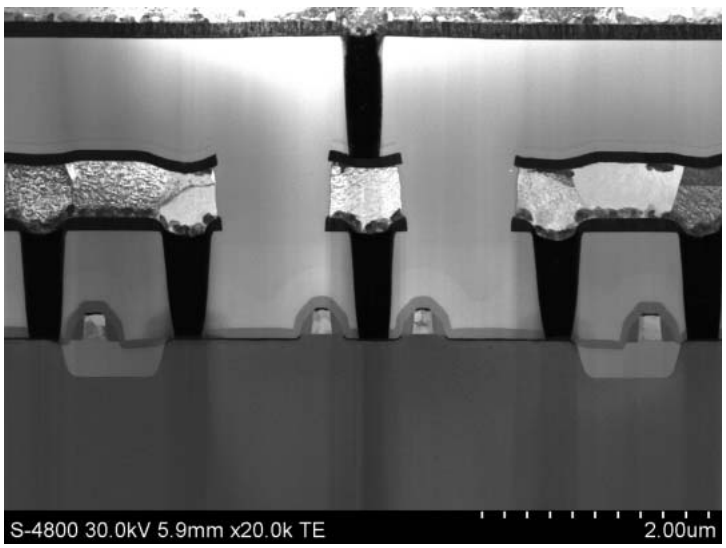


(b) Dark field STEM image

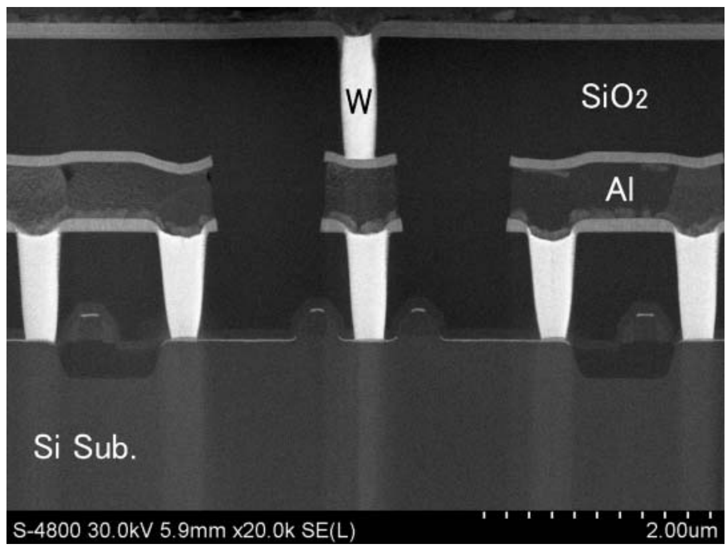
Fig. 6 Observation of copper wiring

4.2 Observation of SRAM

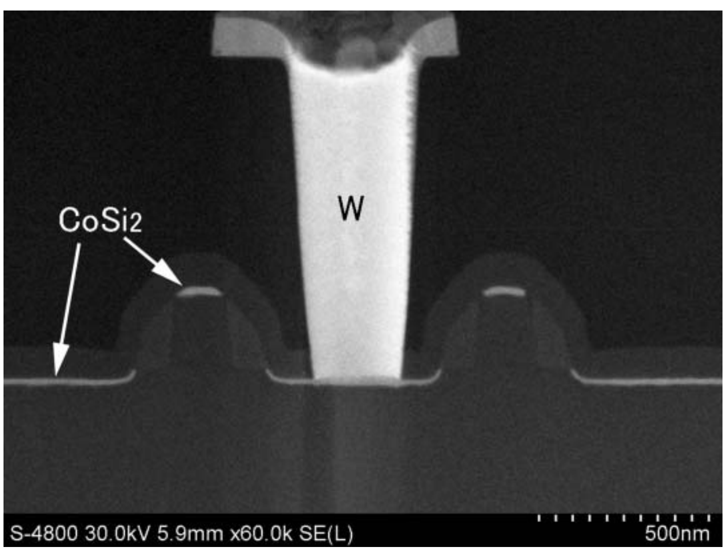
Fig. 7 shows MOS transistor gate area of SRAM recorded in bright field STEM and dark field STEM modes. The specimen has been thinned to a thickness of 150 nm. The bright field STEM image (a) shows grains of aluminum wiring very clearly. The dark field STEM images (b) and (c) show an enhancement of heavy element components like the W-plug and cobalt silicide ($CoSi_2$), as well as light elements like silicon oxide (SiO_2). Compositions are displayed in Z-contrast. The dark field STEM image (d) shows a boundary between the barrier metal of titanium nitride/titanium and W very clearly which facilitates easy evaluation of its coverage and shape.



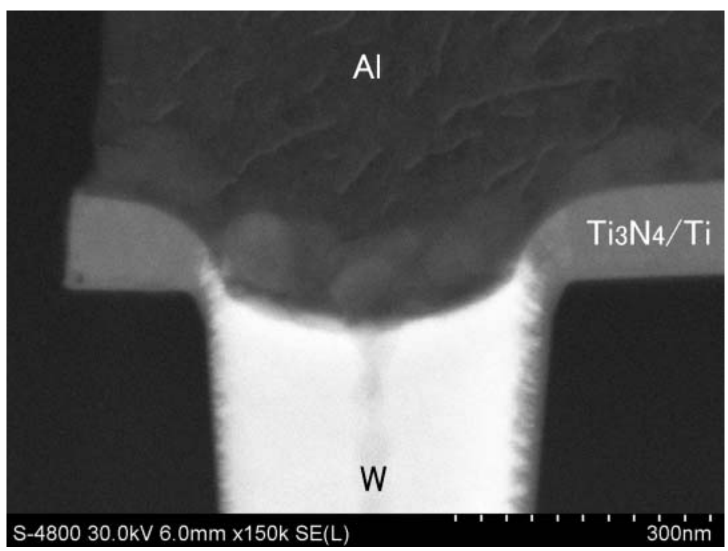
(a) Bright field STEM image



(b) Dark field STEM image



(c) Dark field STEM image (High magnification)



(e) Dark field STEM image (High magnification)

Fig. 7 Observation of SRAM

5. CLOSING REMARKS

The dark field STEM function of the S-4800 highlights a specimen's compositional details utilizing Z-contrast information with normal FE-SEMs that, before now, was not possible to obtain. By making use of this technique, we trust that the S-4800 will be a even more useful tool for evaluation and analysis in various fields of science and technology.

Hitachi High-Technologies Corporation
Tokyo, Japan
http://www.hitachi-hitec.com

For further information, please contact your nearest sales representative.

Printed in Japan (H) **HTD-E050-111** 2005.2