HITACHI SCIENTIFIC INSTRUMENT TECHNICAL DATA SEM

SHEET NO. 98

SUBJECT: THE S-5200 ULTRA-HIGH RESOLUTION FIELD EMISSION SEM
— FEATURES AND SOME APPLICATIONS —

INSTRUMENT: THE S-5200 UHR FE-SEM

CONTENTS

1. INTRODUCTION

Field emission SEMs have been extensively used for process evaluation, particle analysis and CD-measurement in the semiconductor industry. Associated with higher integration and density, however, new technologies such as copper wiring, ArF laser lithography, etc. have been introduced in the processing. Development of new SEMs that have better resolving power than most conventional SEMs has, therefore, been required by the industry for quick evaluation of process conditions.

Fig. 1 shows a general view of the new S-5200 UHR FE-SEM. It has an ultra-high resolution objective lens, enhanced mechanical/electrical stability and improved specimen contamination rate. Thanks to these technological innovations the S-5200 has a guaranteed ultra-high resolution of 0.5 nm (at 30 kV) which is the best in the world. In addition, the S-5200 has a selectable signal detection mode allowing detection of secondary electrons (primarily for topographic information), backscattered electrons (BSE) for composition information, or a combination of these electron signals for optimized image contrast which will suit the specimen or the purpose of microscopy. We report here on the functions, performance and some applications as well as how to use the selectable signal detection mode.

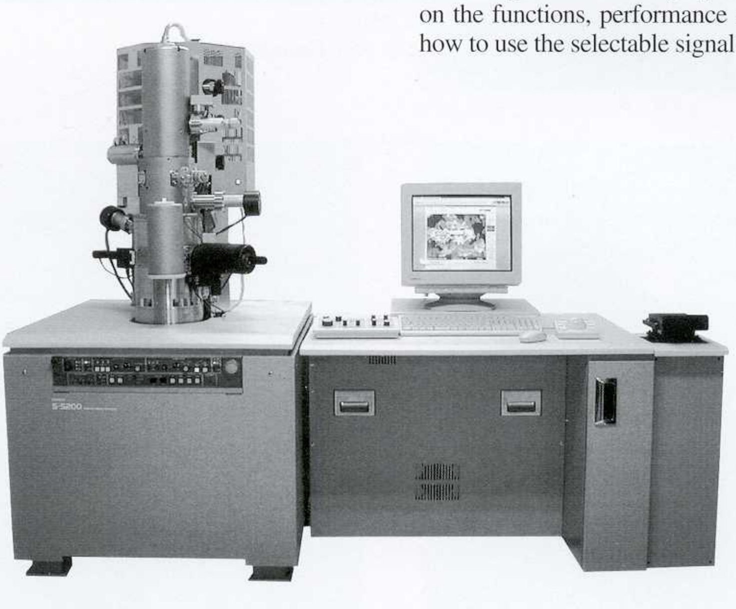

Fig. 1 A general view of the S-5200 UHR-FE-SEM

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2. FEATURES OF THE S-5200

The S-5200 has the following functions and performance features.

1) Ultra-high resolution objective lens
   (Resolution: 1.8 nm at 1 kV or 0.5 nm at 30 kV)
2) Signal detection mode
   - Secondary electron (SE) mode
   - Signal control mode
     (Detection ratio of SE and BSE signals can be set arbitrarily.)
   - Low voltage BSE mode (Option)
   - Signal mixing mode (Option)
   - YAG BSE mode (Option)
   - STEM mode (Option)
3) Low contamination rate
   High speed beam blanking, dry vacuum system, and anti-contamination cold trap (Option)
4) High mechanical stability
   Allowable floor vibrations: 10 μm at 5 Hz)
5) SEM operation on WindowsNT® GUI and networking

We report on details for the above 1) and 2).

2.1 Ultra-high resolution objective lens

We have developed a new low-aberration objective lens for ultra-high resolution applications. It allows 1.8 nm at 1.0 kV (See Fig. 2-a Gold particles on magnetic tape) or 0.5 nm at 30 kV (See Fig. 2-b Sputtered platinum particles on carbon) guaranteed.

We trust that this ultra-high resolution performance is sufficient for evaluation of present and future semiconductors as well as advanced functional materials and that it will promote development and research in modern science and engineering. The S-5200 has an excellent mechanical stability by a factor of 3 to 5 in comparison to conventional instruments. It allows a high resolution work in laboratories where it has been difficult with conventional instruments.

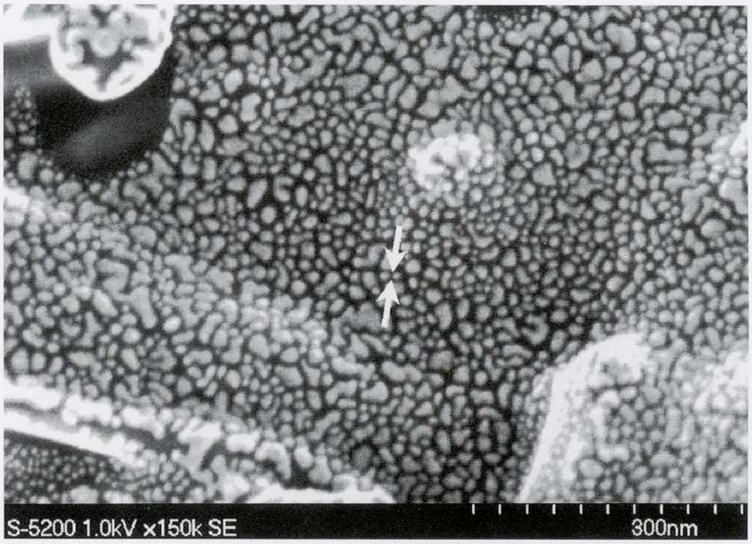

Fig. 2-a

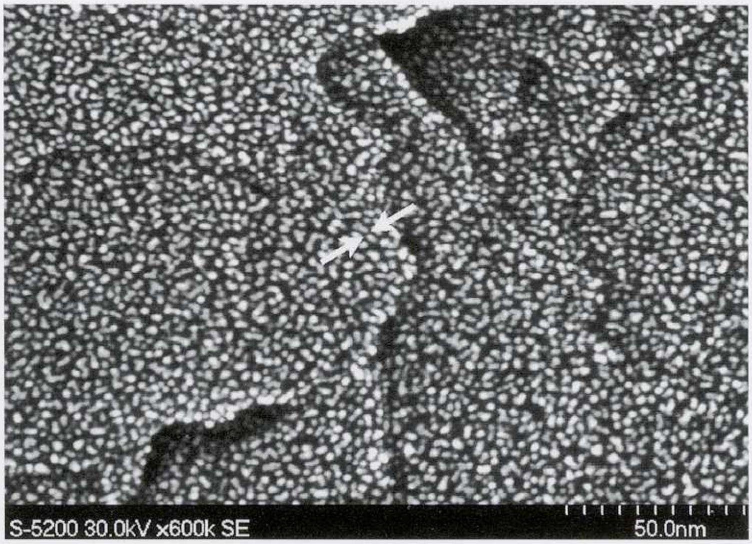

Fig. 2-b

Fig. 2 High resolution image

2.2 Selectable signal detector mode

When the primary beam of electrons strikes a specimen, various electrons are emitted each carrying information characteristic of the specimen. These electrons are detected using various detectors and the signals are used to form images of the specimen. Fig. 3 shows detectable signals and available imaging information. Fig. 4 shows various detector positions. As shown in Fig. 3, the S-5200 allows detection of backscattered electrons at low angles (BSE-L) and the same at high angles (BSE-H) using SE and low voltage BSE detectors. The SE/BSE-L ratio of the SE detector can be changed by signal control mode. Therefore we can control for optimum contrast to suit the specimen and/or purpose of observation. In addition, a transmitted electron detector is available at option. It allows the S-5200 to operate as a scanning transmission electron microscope or STEM. Table 1 shows features of each detector mode.

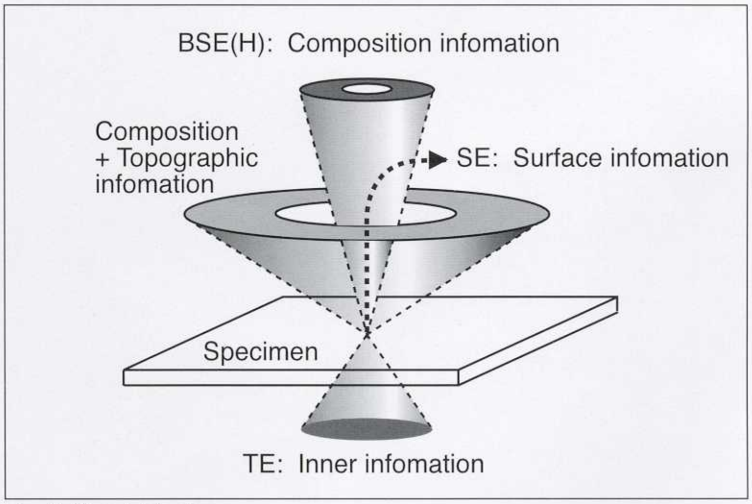

Fig. 3 Signal detection

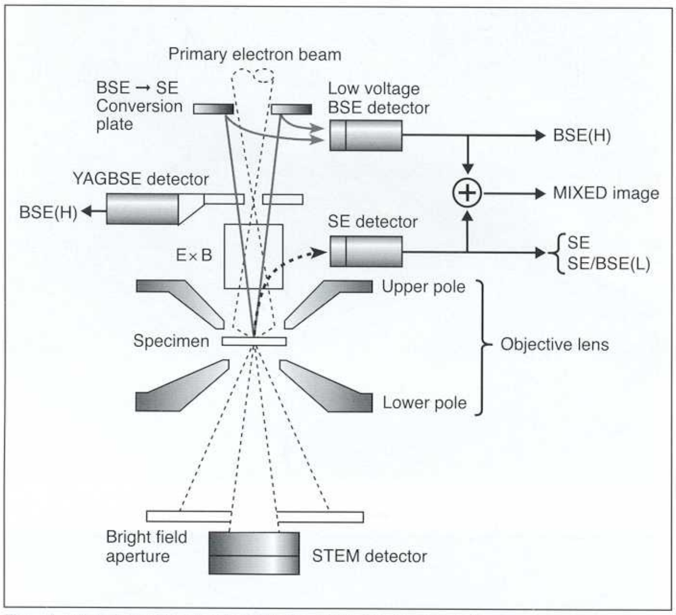

Fig. 4 Various detector positions and arrangements

Table 1 Various detector modes & their features

Detector mode	Detector signal	Detector	Image linfomation
Secondary Electrons	SE	SE	Specimen surface, Topographic image
Signal Control mode	SE + BSE-L (variable ratio)	SE	Reduced edge-contrast, Charge-up Topographic composition image
Low voltage BSE mode	BSE-H	Low voltage BSE detector	Composition image BSE detector Vacc.~5kV
MIX mode	SE or SE + BSE-L + BSE-H	SE Low voltage BSE detector	Surface structure + Composition image
YAG BSE mode	BSE-H	YAG-BSE detector	Composition image Vacc. 5kV~
STEM mode	TE	STEM Detector	Inner structure

2.2.1 Signal control mode/Low voltage BSE mode

Fig. 5 shows a composite of alumina and nickel recorded in signal control mode and low voltage BSE mode. Fig. 5-a was recorded in SE mode. It shows topographic contrast of the specimen surface so that both nickel particles and alumina are about the same contrast. It is difficult to tell distributions of nickel particles. Fig. 5-b was recorded in signal control mode. The BSE image shows both alumina and nickel particles reflecting contrast of their average atomic numbers so that it is easy to tell distributions of each particle clearly. This mode allows change of image contrast easily by changing SE/BSE-L ratio. Fig. 5-c was recorded in low voltage BSE mode which has been difficult before. It shows composition information on the specimen surface.

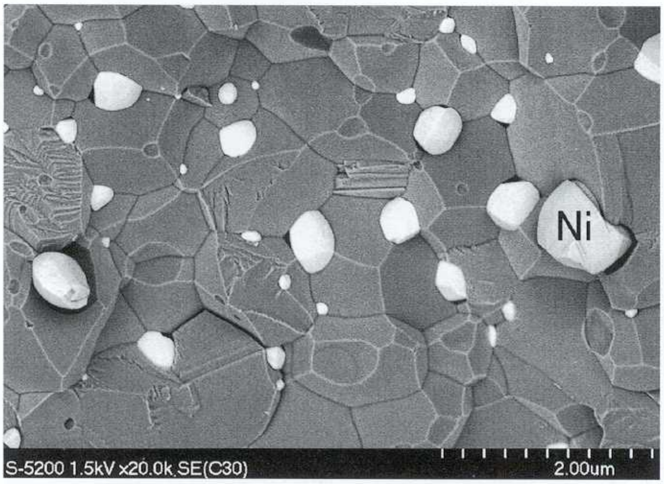

Fig. 5-b

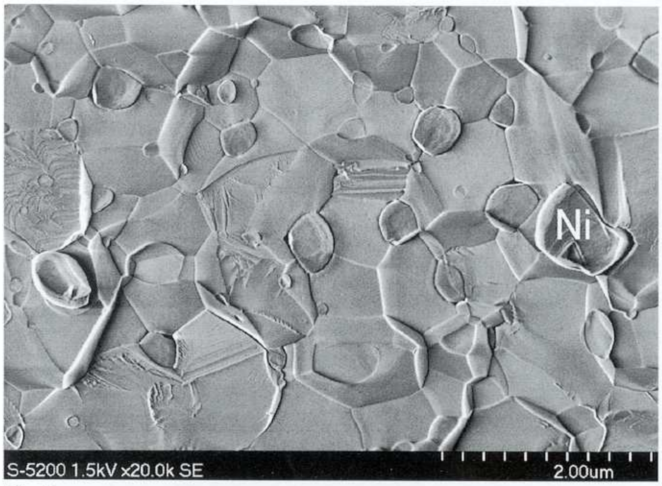

Fig. 5-a

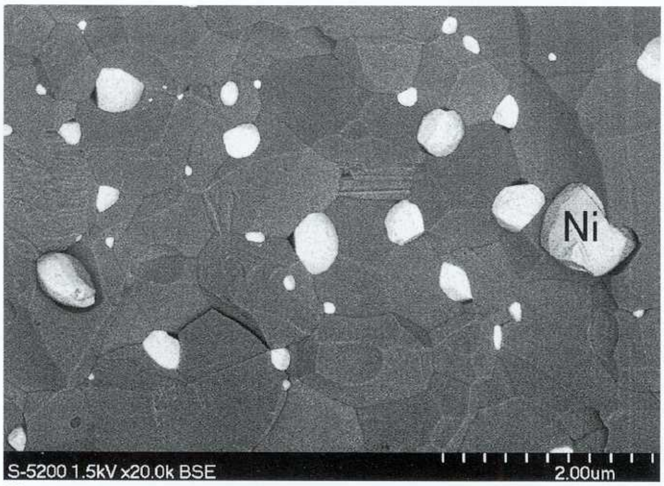

Fig. 5-c

Fig. 5 Alumina/Nickel composite observation Specimen, courtesy of Associate Prof.. T. Sekino and Prof. K. Niihara, ISIR, Osaka University

2.2.2 Signal mixing mode

Fig. 6 shows Pt/C catalyzer used for processing automobile exhaust gas or for electrodes of fuel cells. Fig. 6-a was recorded in SE mode and it shows surface structures of C-particles. Fig. 6-b was recorded in low voltage BSE mode. It shows distributions of Pt-particles of about 10 nm or smaller. Fig. 6-c was recorded in MIX mode. It allows overlapping 6-a and 6-b images. It also allows evaluation of surface structures of C-particles and distribution of Pt-particles quickly.

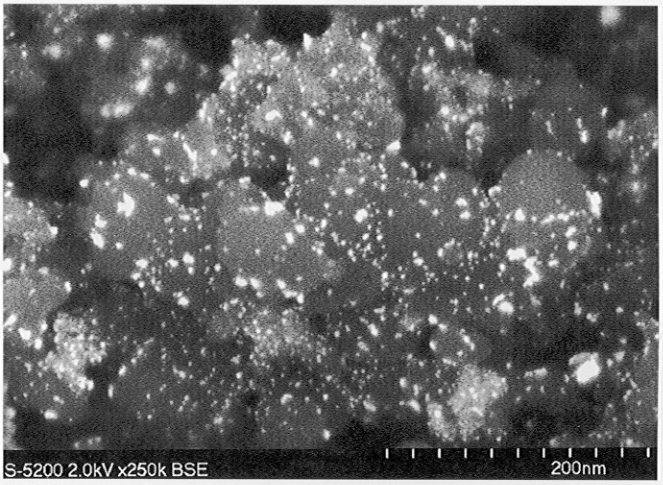

Fig. 6-b

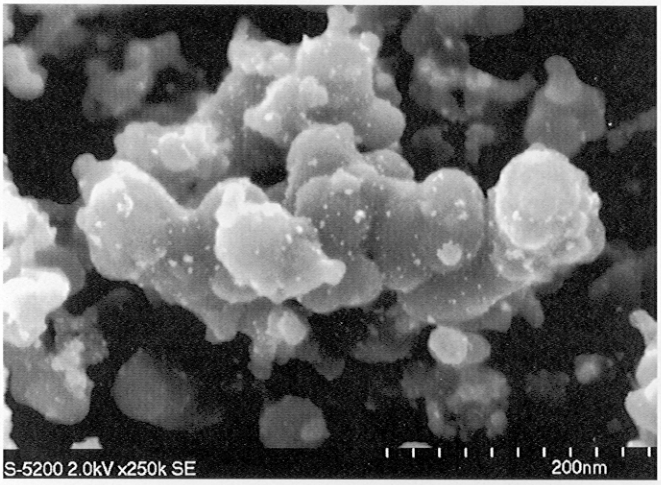

Fig. 6-a

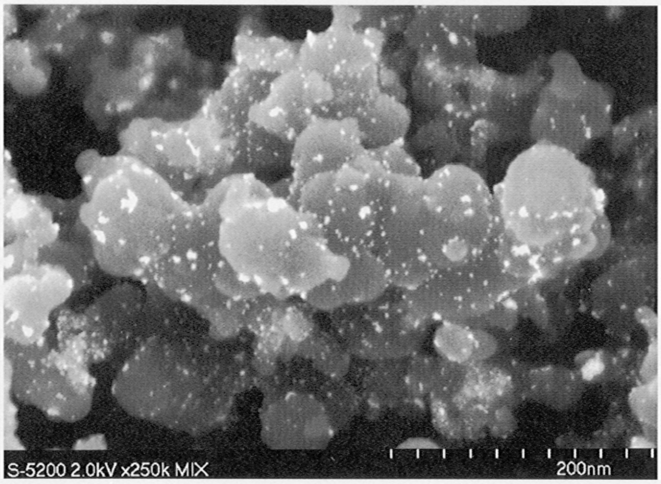

Fig. 6-c

Fig. 6 Catalyzer observation

3. MATERIALS SCIENCE APPLICATIONS

3.1 ITO film

Fig. 7 shows ITO (Indium Tin Oxide) film recorded in SE mode. This material is widely used on LCD displays for electrodes. The picture was recorded at a high magnification of x400,000 and at an accelerating voltage of 5 kV. It shows surface details very clearly.

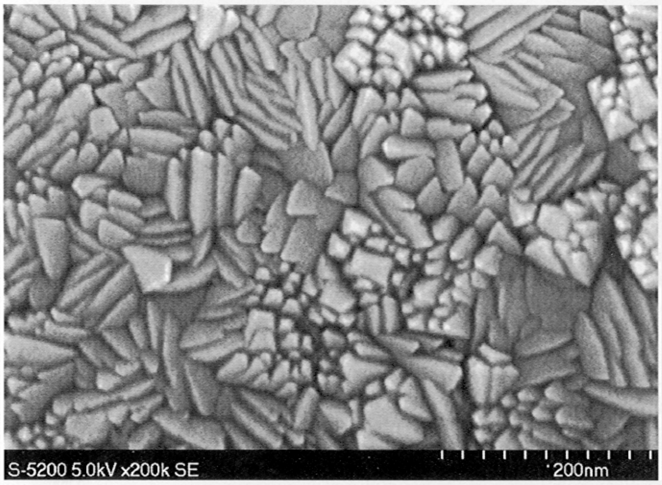

Fig. 7-a

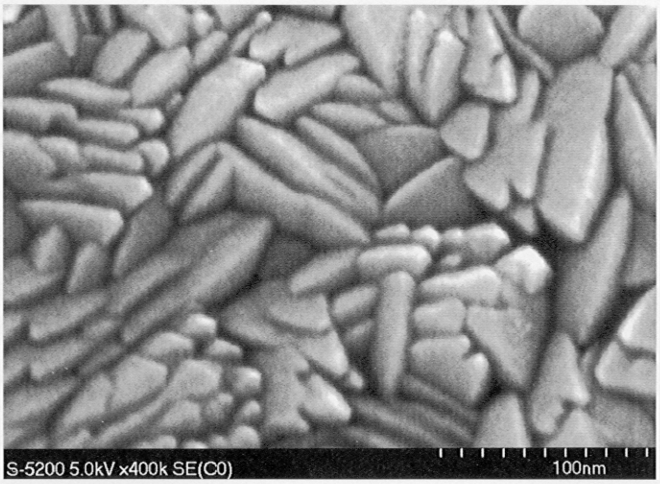

Fig. 7-b

Fig. 7 ITO film observation

3.2 GMR film

Hard disks, which are primary memory devices for PCs, are moving toward higher densities and memory capacities. Fig. 8 shows a GMR (Giant Magneto Resistive) film which supports readout of high density memories. The picture was recorded in YAG-BSE mode. The S-5200 coupled with a high sensitivity YAG-BSE detector allows evaluation of thin film specimens in nm orders.

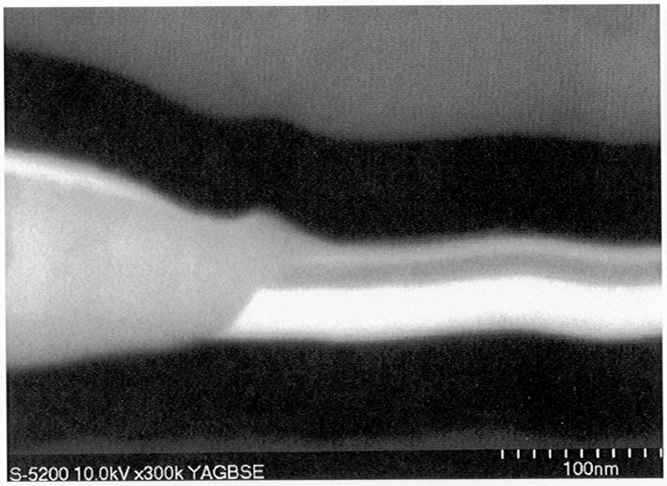

Fig. 8-b

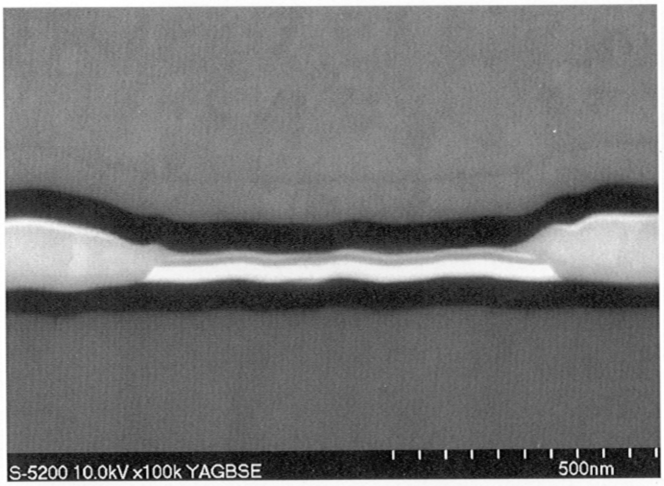

Fig. 8-a

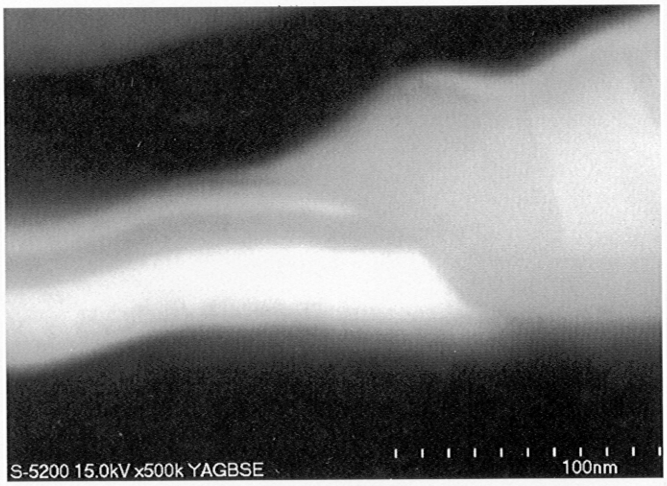

Fig. 8-c

Fig. 8 GMR film observation

4. SEMICONDUCTOR APPLICATIONS

4.1 SRAM

Fig. 9 shows a sectional structure of SRAM (Static Random Access Memory) recorded in signal control mode. The specimen was first fractured and mechanically polished. It was finally wet-etched using a solution of several percent of HF, etc. It was observed without coating. Operating conditions were optimized for preventing charging, particularly on insulator. Fig. 9-a shows recession and inter-metallic compounds such as Ti$_x$Al. Fig. 9-b shows grain contrast of W-plug. Fig. 9-c shows a shape of spacer (Si$_3$N$_4$) and a shape of poly-Si gate electrode. It also shows CoSi$_2$ layer of about 20 nm thick at high contrast very clearly.

Optimized control of SE and BSE allows display and analysis of inner structures of semiconductor devices which are moving toward higher integration and density.

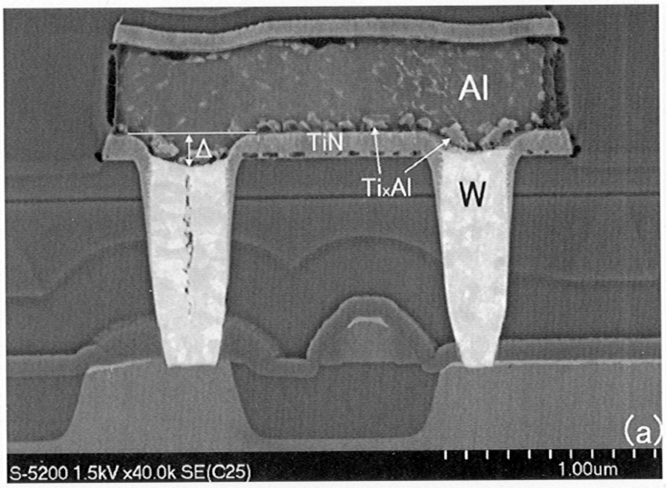

Fig. 9-a

Fig. 9 SRAM observation (Cross-sectional view)

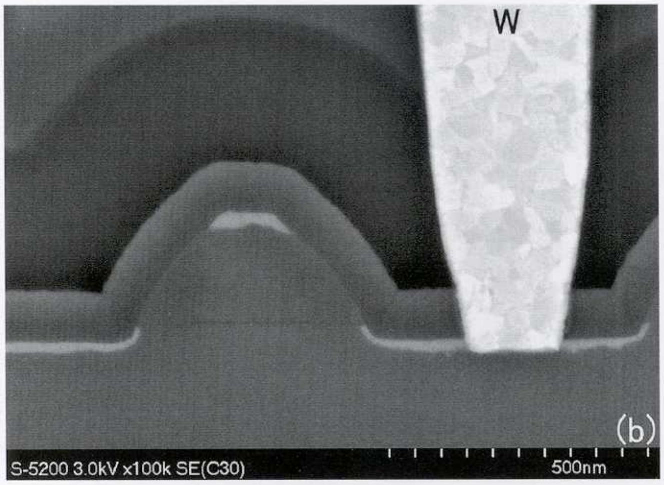

Fig. 9-a

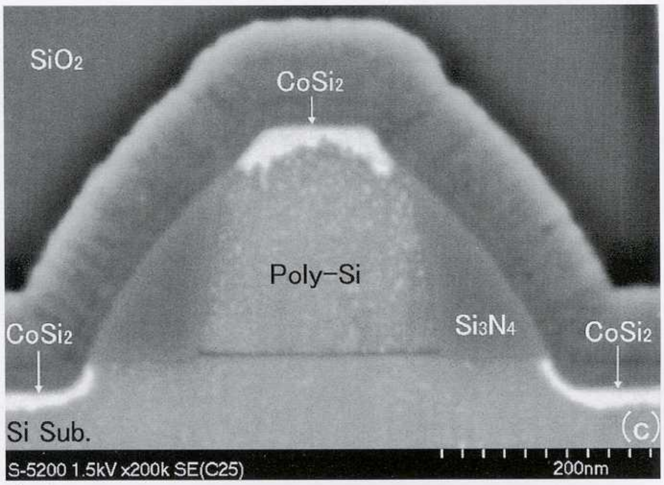

Fig. 9-c

4.2 HSG capacitor

HSG(Hemispherical grain) capacitor has been employed for capacitor electrodes for allowing high density integration and maximizing capacitors. Figs. 10-a and 10-b show a cross-sectional view of the same area. Fig. 10-a was recorded in SE mode. Fig. 10-b was recorded in low voltage BSE mode. The specimen was prepared by cleaving. The purpose of microscopy was to evaluate thickness and uniformity of Ta_2O_5 which was used for insulating film of capacitors. The SE image shows pillar and other fine surface structures of TiN. Ta_2O_5 film, however, shows topographic structures which were caused during cleaving. Image contrast of the film structure and its vicinity is mixed making the evaluation difficult. The low voltage BSE image shows Ta_2O_5 film clearly thanks to composition contrast. It allows evaluation of film thickness and uniformity without problems. The SE image doesn't show the boundary between silicon nitride and silicon oxide due to specimen charging. The low voltage BSE image shows the boundary very clearly despite the small composition difference.

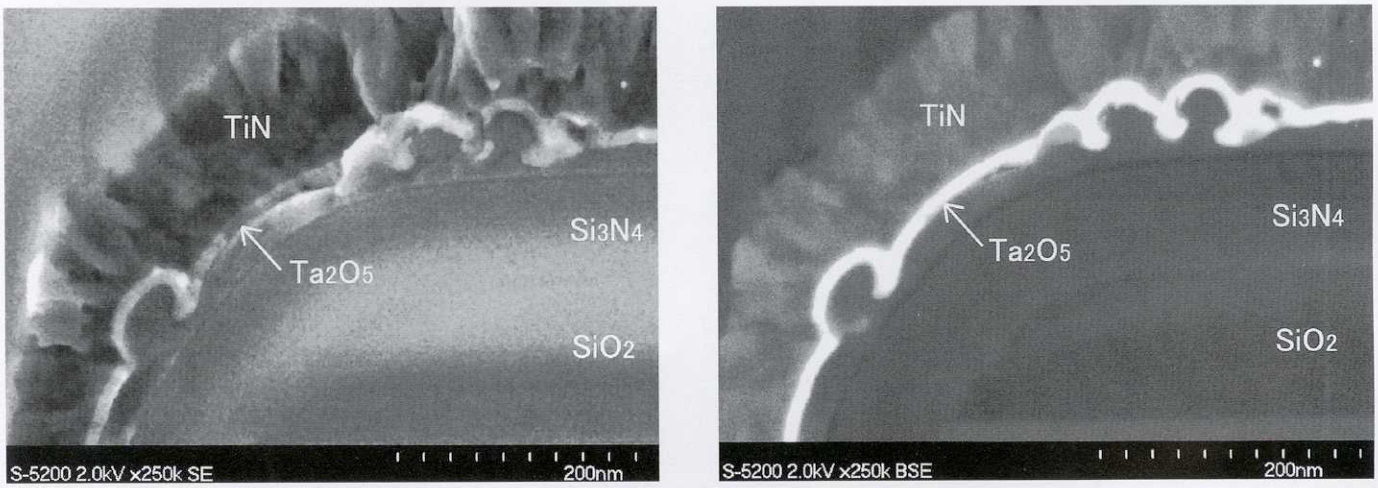

Fig. 10-a

Fig. 10-b

Fig. 10 HSG capacitor observation (Cross-sectional view)

4.3 Photo-resist

Fig. 11 shows a high resolution image of a photo-resist pattern which has a line width of about 60 nm, recorded in SE mode. A high resolution image taken at a low operating voltage clearly shows patterns and a small amount of scum on substrate. This is a promising sign of the S-5200 being capable of evaluation of next generation devices. (The SDR-2020 critical point dryer was used for specimen preparation.)

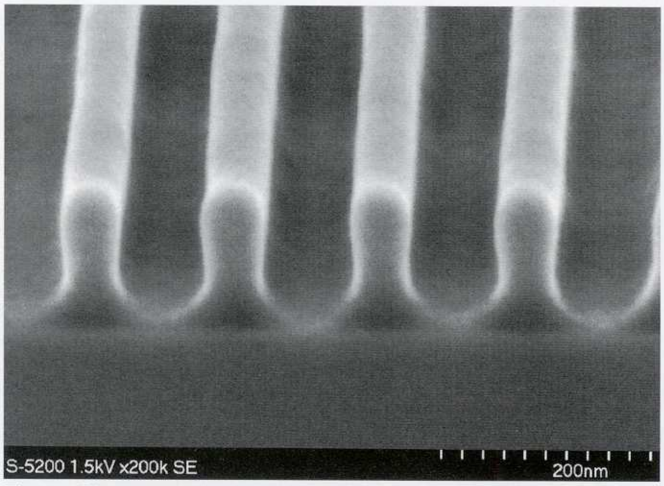

Fig. 11 Photo-resist pattern observation (Bird's eye view)

5. BIOLOGICAL APPLICATIONS

5.1 Blood platelet

The immunological SEM technique allows us to understand distribution of specific proteins on cell surfaces when proteins are reacted with antibody and colloidal gold particles. Fig. 12 shows B_3 integrin on activated human blood platelet, marked by colloidal gold particles of about 10 nm. As shown in Fig. 12-b, it is possible to observe specimen morphology and distribution of colloidal gold simultaneously by using signal control mode. Notice that gold markers are visible in white contrast.

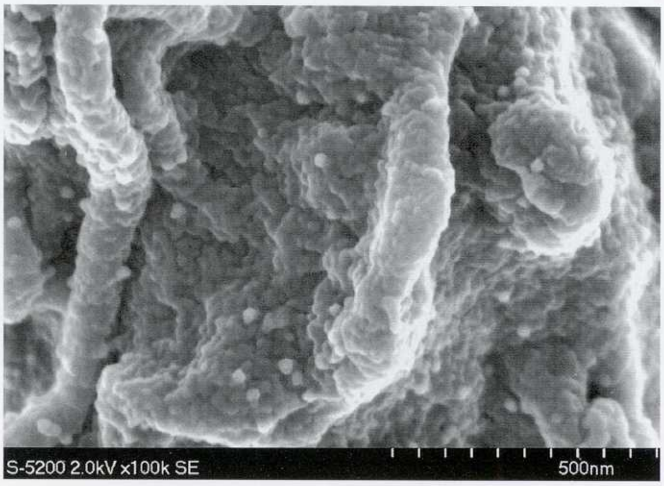

Fig. 12-a

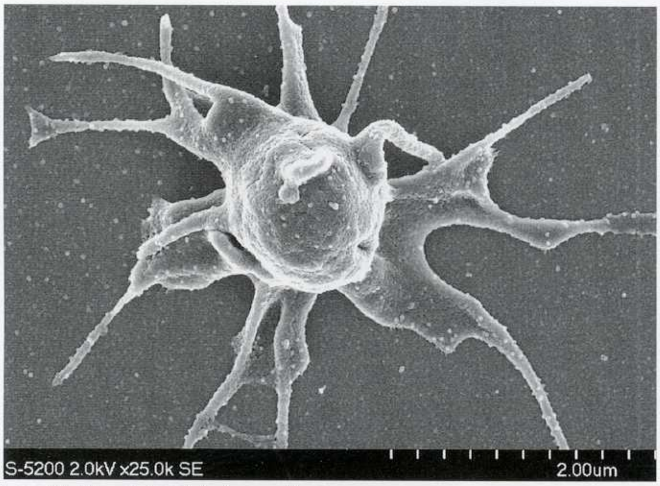

Fig. 12 Blood platelet observation

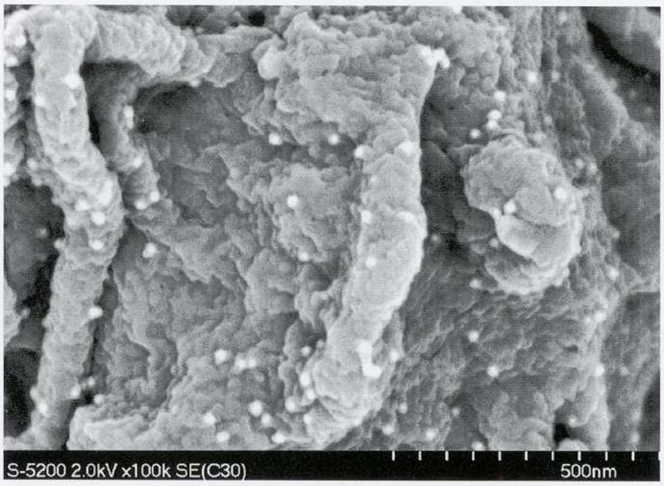

Fig. 12-b

Specimen, courtesy of Dr. H. Suzuki, Dept. of Cardiovascular Res., The Tokyo Metropolitan Inst. Med. Sci.

5.2 Virus

Fig. 13 shows adeno-virus, which is attracting keen attention in the gene therapy vector. It was recorded in STEM mode. The specimen was prepared by using the normal TEM specimen preparation techniques which include fixation, dehydration, embedding, sectioning, and staining. This virus is well known for selective propagation in cancer cells. The low voltage STEM image clearly shows periodic grid structures of viruses.

6. CLOSING

The S-5200 is a high performance SEM as introduced in the foregoing. Unlike conventional SEMs, it allows quick selection from among various information generated from specimens. We trust that the S-5200 will be useful for evaluation of various semiconductor devices and advanced materials. It can also be used for biological applications beyond the limit of conventional SEMs.

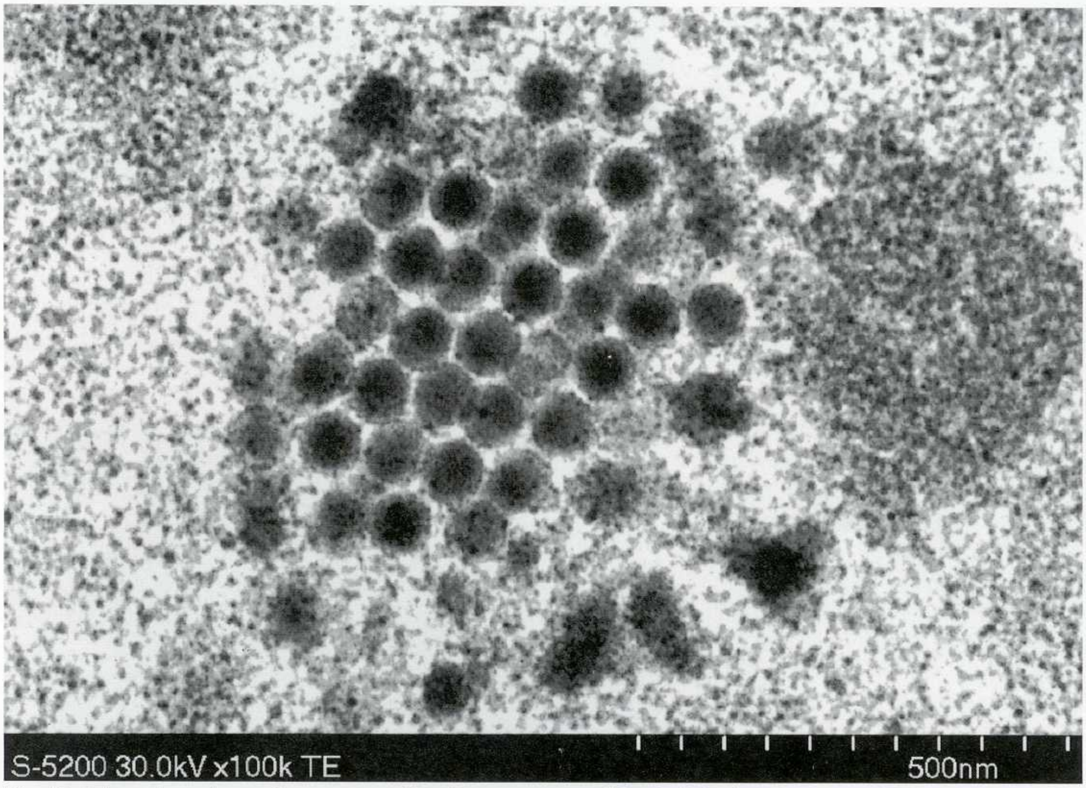

Fig. 13 Adeno-virus observation

Specimen, courtesy of Dr. S. Fukuda, Laboratory of Electron Microscopy, Faculty of Medicine, University of Tokyo

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