SUBJECT: SITE-SPECIFIC 3-DIMENSIONAL CHARACTERIZATION USING AN FIB MICRO-SAMPLING TECHNIQUE

INSTRUMENT: THE FB-2000A FOCUSED ION BEAM SYSTEM
THE HD-2000 ULTRA-THIN FILM EVALUATION SYSTEM
THE HF-2200 COLD FIELD EMISSION TRANSMISSION ELECTRON MICROSCOPE

CONTENTS

Page

1. INTRODUCTION

FIB (Focused Ion Beam) systems allow fine milling of site-specific areas. These systems have been extensively used for TEM specimen preparation and development and/or failure analysis of semiconductor devices. An FIB micro-sampling technique, which has been developed from the FIB technique, is well-known for its unique ability to make selected site-specific TEM specimens available directly from bulky samples.

Failure analysis of semiconductor devices often require plan and sectional views simultaneously. Here in this Technical Data, we report on specimen preparation for plan and cross-sectional views of the same specimen area of interest using the micro-sampling technique as well as observations on that area.

2. METHOD

Fig. 1 illustrates the micro-sampling technique for specimen preparation of the same area for plan and cross-sectional view observation. A plan view specimen(b) is cut out from a bulky sample(a). A plan view image is observed using a specimen of about a few µm thick(c). Then, a cross-sectional specimen(d) is prepared using the micro-sampling technique.

After a cross-sectional observation(e), a plan view specimen of a specific area of interest is prepared(f) and a plan view image is observed(g).

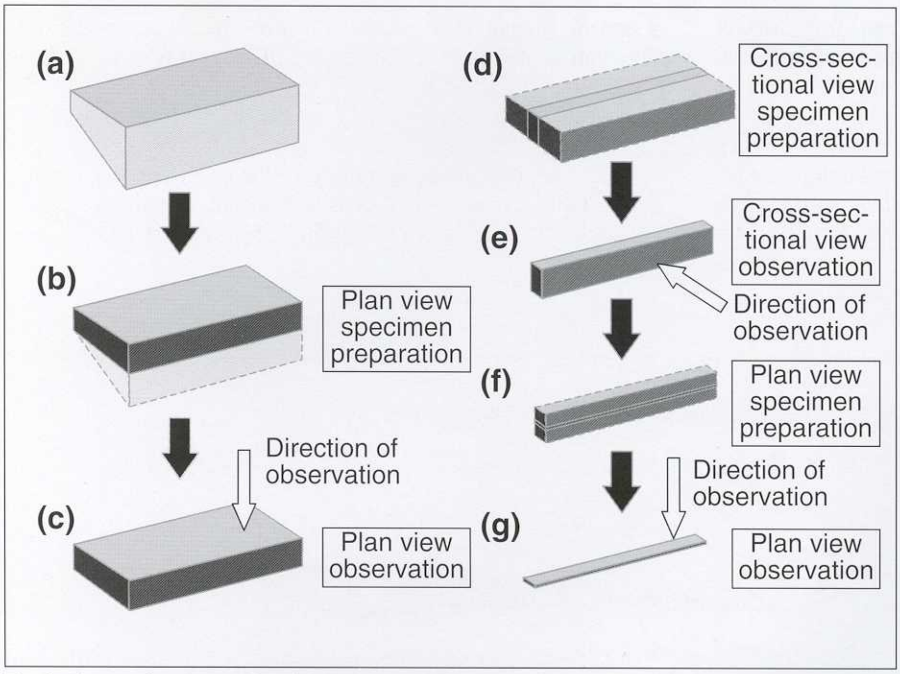
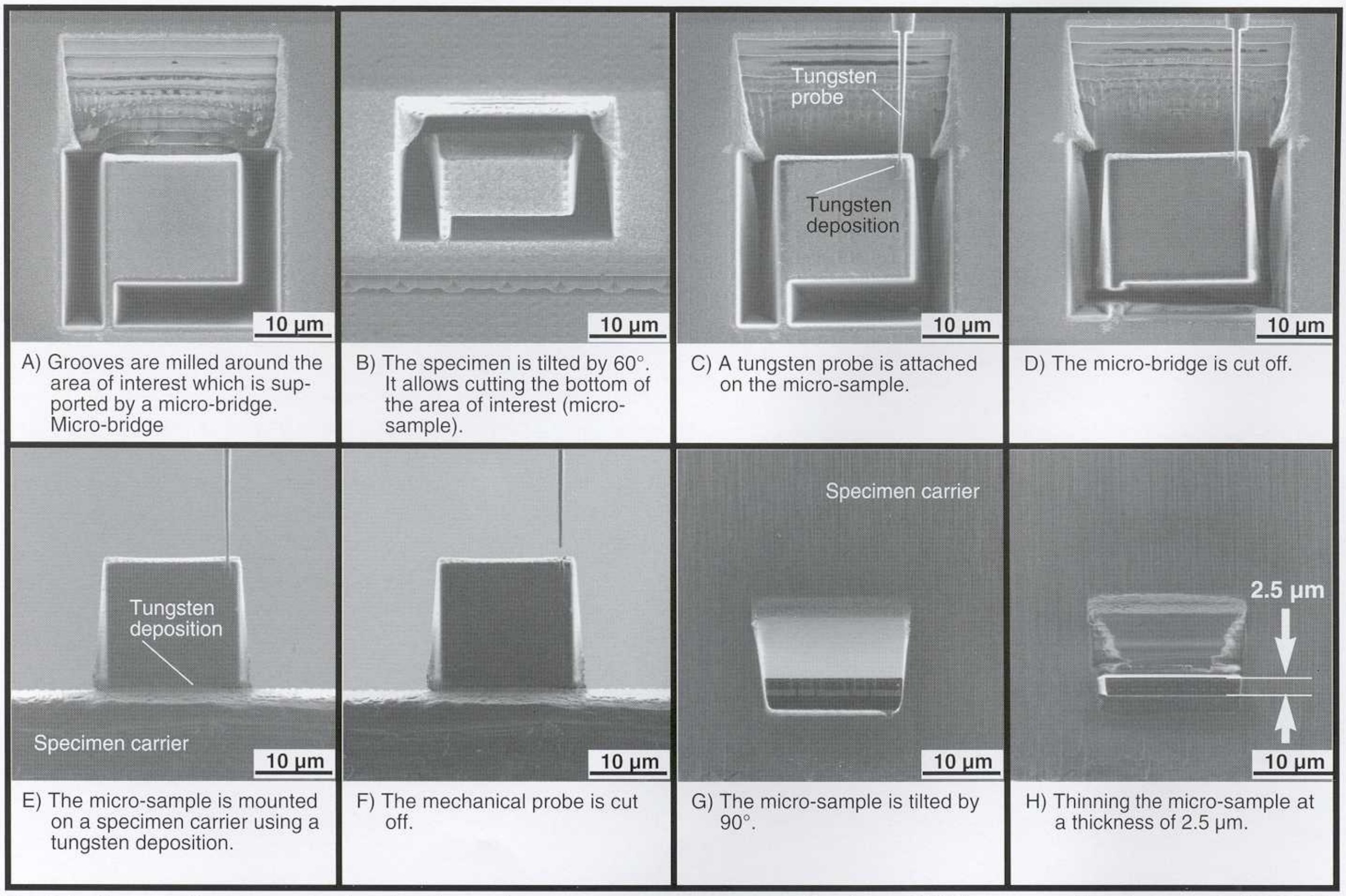


Fig. 1 Plan and cross-sectional view specimen preparation from the area of interest using the micro-sampling technique and respective observations

3. APPLICATIONS

3.1 A plan view / cross-sectional view / plan view image observation

Fig. 2 shows a series of the micro-sampling process using a SRAM sample which is used for micro-processors. A) shows grooves milled around the area of interest leaving a portion of the sample for supporting the cutout specimen in position. B) shows the same sample tilted by 60° so that the bottom of the area of interest may be cut. C) shows a tungsten probe adhered on the sample. D) shows the cutout specimen after cutting the support. E) shows the cutout micro-sample mounted on a carrier. F) shows the mechanical probe cut off using the FIB. G) shows the micro-sample viewed from the direction of the FIB. H) shows the micro-sample thinned at about a thickness of 2.5 μm for the first plan view observation.



A) Grooves are milled around the area of interest which is supported by a micro-bridge. Micro-bridge

B) The specimen is tilted by 60°. It allows cutting the bottom of the area of interest (micro-sample).

C) A tungsten probe is attached on the micro-sample.

D) The micro-bridge is cut off.

E) The micro-sample is mounted on a specimen carrier using a tungsten deposition.

F) The mechanical probe is cut off.

G) The micro-sample is tilted by 90°.

H) Thinning the micro-sample at a thickness of 2.5 μm.

Fig. 2 A micro-sampling process for plan view observation Specimen: SRAM memory cell Instrument: FB-2000A

Fig. 3 shows a dark field STEM (DF-STEM) image(a) of the plan view specimen and a higher magnification image(b). The DF-STEM image shows the shape of plugs and relative positions of plugs and metal wirings very clearly. Then, the upper part of the specimen, which is a square masked area in Fig. 3(b), is cut out using the micro-sampling technique and a cross-sectional specimen is prepared. Fig. 4 shows this preparation process. For cutting out a plan view specimen(a), which has the same field of view as Fig. 3a, a tungsten probe is attached using a tungsten deposition(b). A cross-sectional observation area is cut off using the FIB(c). It is mounted on a carrier and fixed on it using a tungsten deposition(d). The tungsten probe is cut off using the FIB(e). Tungsten is deposited on the cross-sectional specimen for surface protection(f). This completes mounting of the cross-sectional specimen on the carrier. The cross-sectional specimen is then thinned to a thickness of about 0.5 μm for transmission microscopy(g).

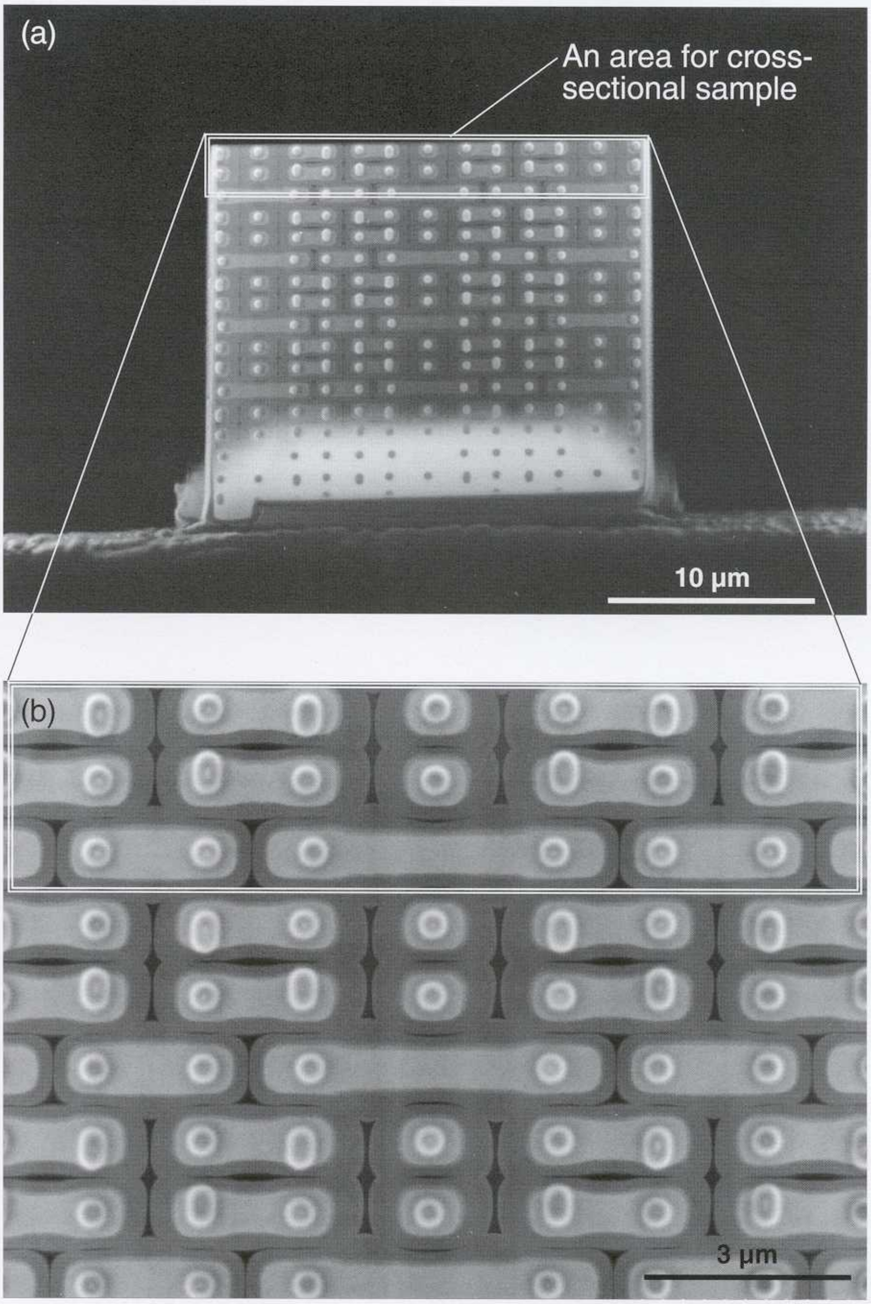
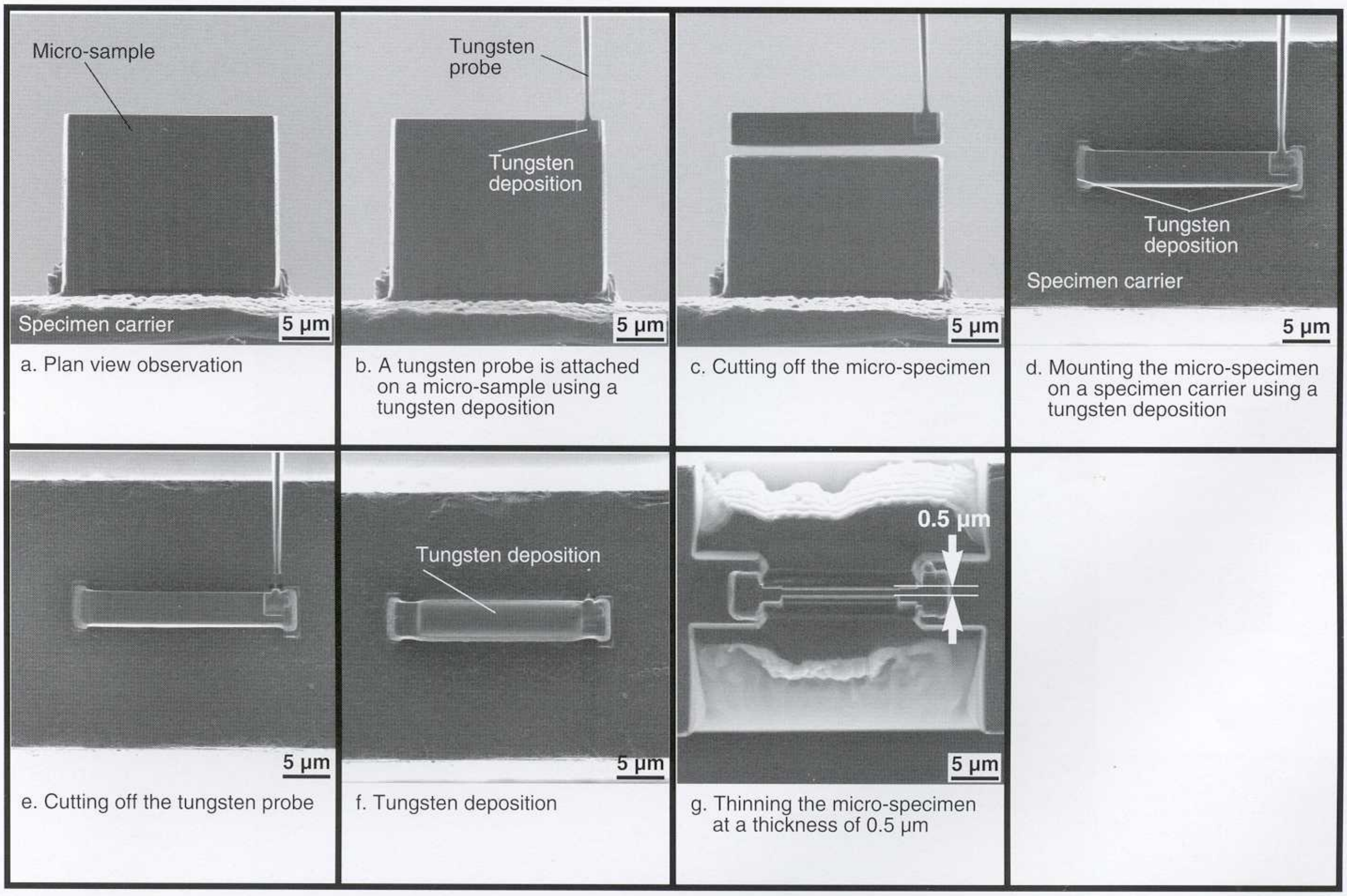


Fig. 3 A dark field STEM image of a plan view specimen Instrument: HD-2000 Accelerating voltage: 200 kV



a. Plan view observation

b. A tungsten probe is attached on a micro-sample using a tungsten deposition

c. Cutting off the micro-specimen

d. Mounting the micro-specimen on a specimen carrier using a tungsten deposition

e. Cutting off the tungsten probe

f. Tungsten deposition

g. Thinning the micro-specimen at a thickness of 0.5 µm

Fig. 4 A cross-sectional specimen preparation process

Fig. 5 shows a bright field STEM image of the cross-sectional specimen. There are white contrast areas along the right and left sides of plugs. For a plan view observation of these areas closely, we have prepared a specimen by cutting out a square masked area in Fig. 5 at right angles. The plan view specimen preparation process is fundamentally the same as shown in Fig. 4. The final thickness of the specimen is about 0.1 μm.

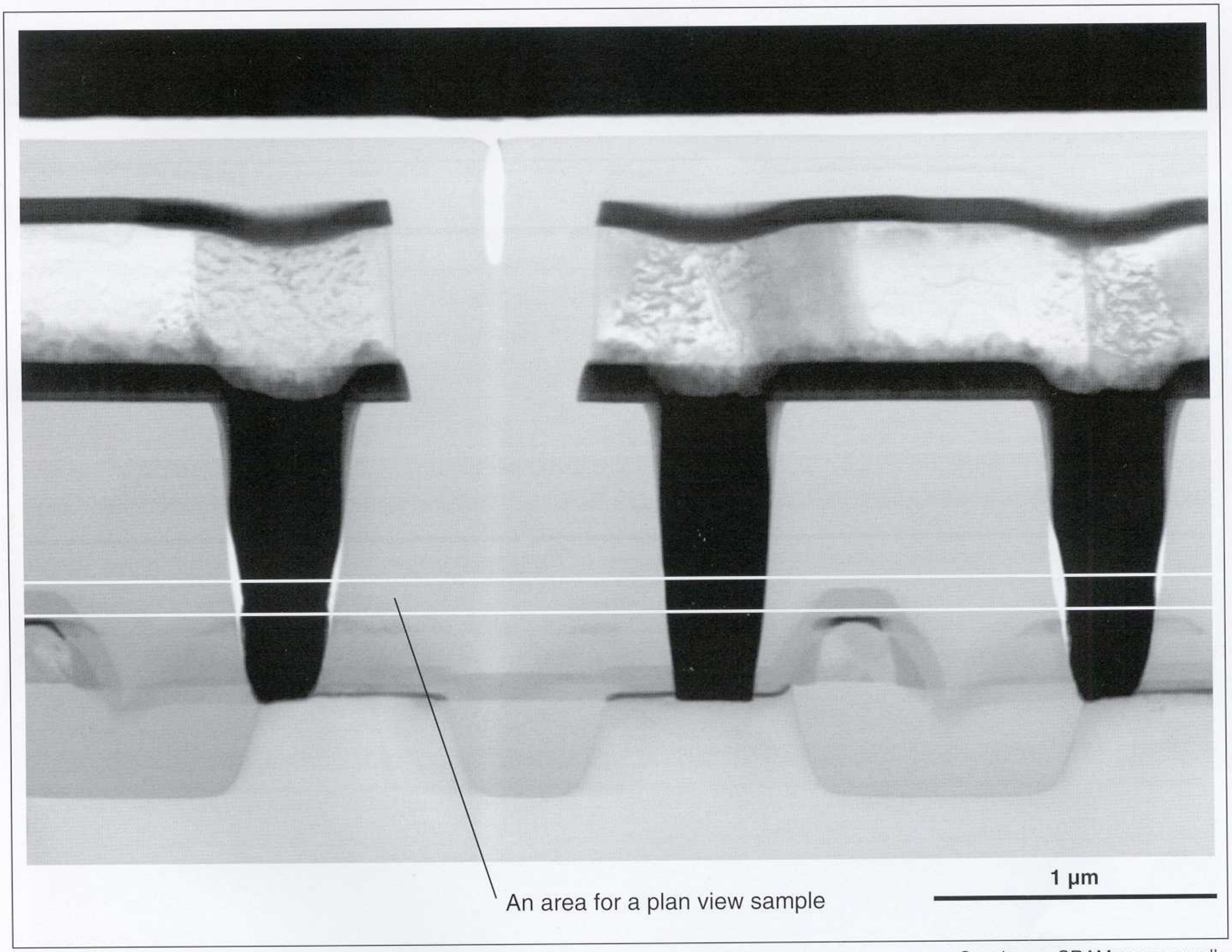


Fig. 5 A bright field STEM image of a cross-sectional specimen

Specimen: SRAM memory cell
Instrument: HD-2000
Accelerating voltage: 200 kV

Fig. 6 shows a plan view image of the plug specimen prepared. Fig. 6(a) is a BF-STEM image corresponding to Fig. 5. Figs. 6(b) and (c) are high magnification images of the left and the central plugs. Here, we can see differences in shape of both plugs and their peripheral structures very clearly.

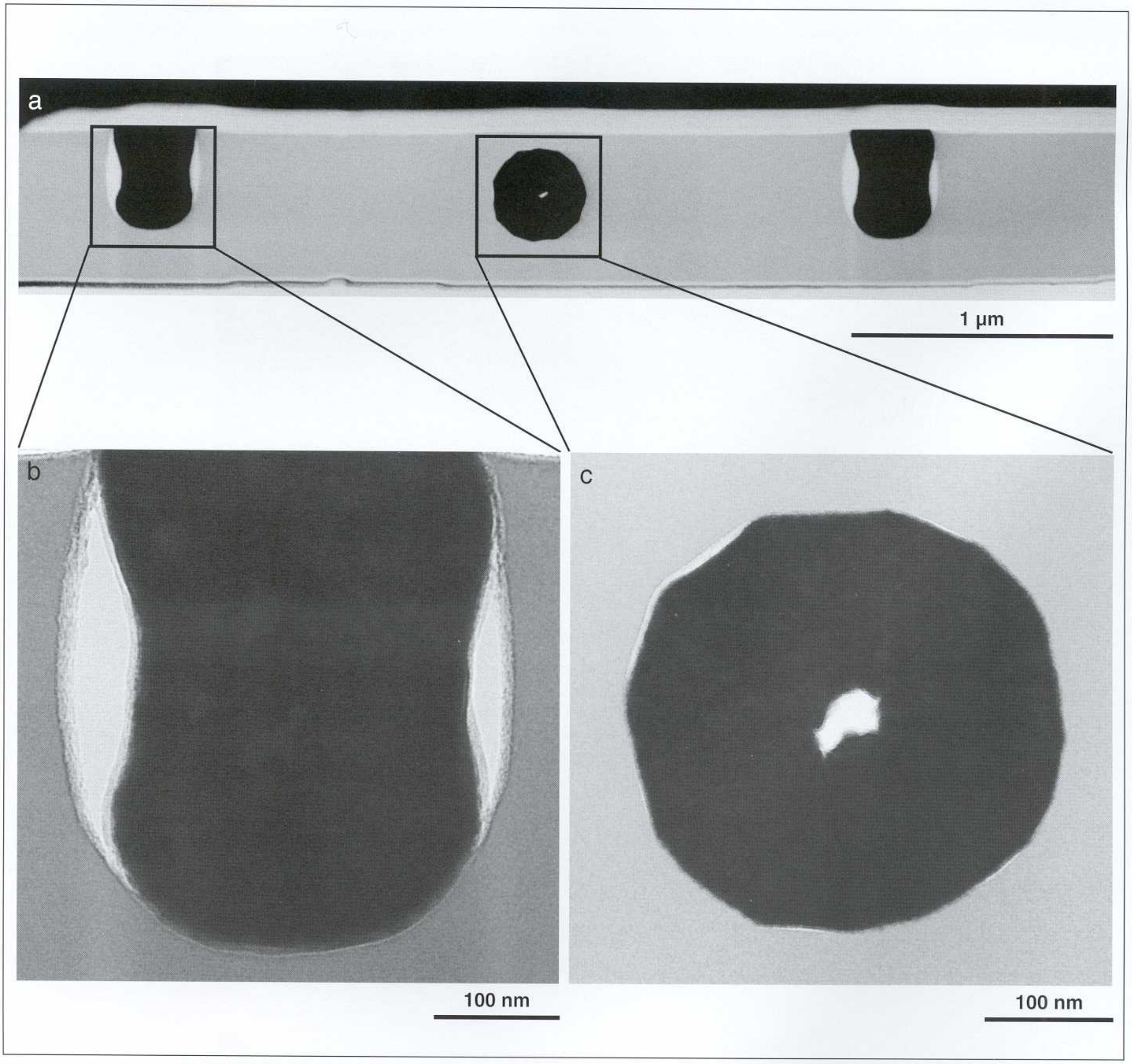
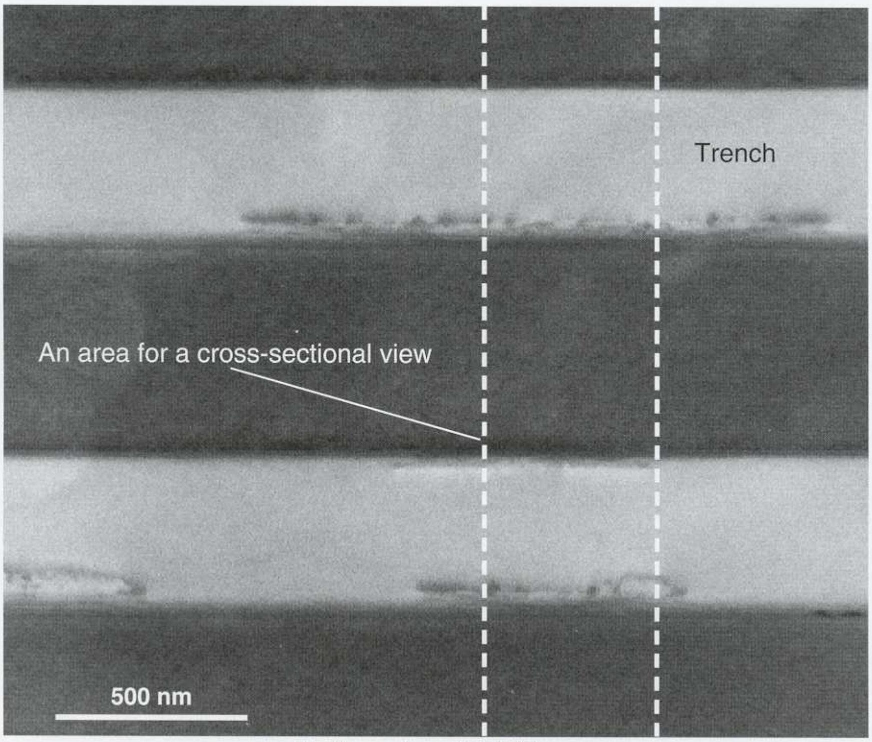


Fig. 6 A bright field STEM image of a plan view specimen

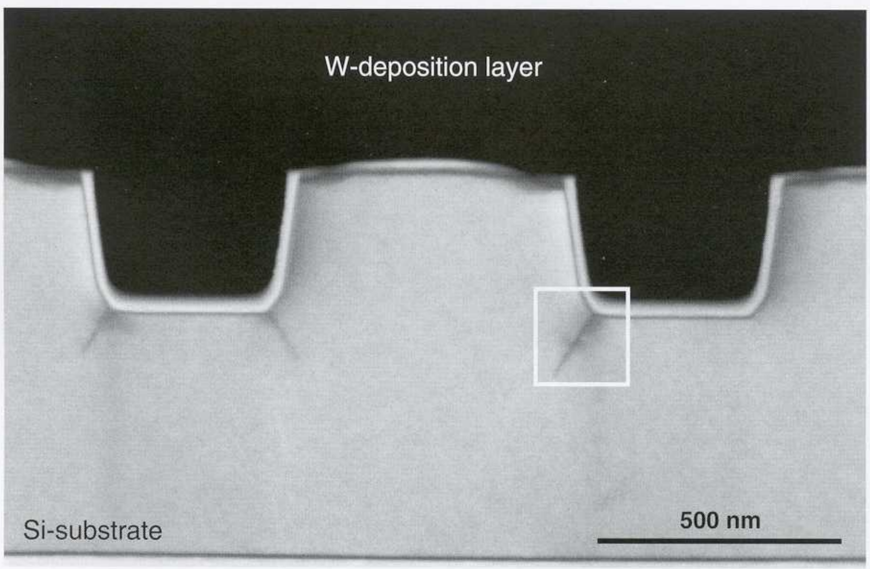
Instrument: HD-2000
Accelerating voltage: 200 kV

3.2 256M DRAM plan view - cross-sectional view

Fig. 7 shows a 3-dimensional view of defects of a test element group (TEG) pattern used on a 256M DRAM. Fig. 7a is a plan view TEM image of a leak position found by an optical beam induced current (OBIC) technique. The specimen was prepared by removing an oxide film by chemical polishing and it was polished to a thickness of about 0.6 μm at the back of Si-substrate. Along the trench which is seen brightly, crystal defects are generated. Fig. 7b is a cross-sectional TEM image of a micro-sample cut out from an area shown by dotted lines on Fig. 7a and thinned to about 0.1 μm. We can see that all crystal defects in Si-substrate are generated at bottom corners of trench structures. Fig. 8 is a high resolution image of a part of bottom corners of a trench. Here we can see the crystal defect generated along (111) plane.



a. A plan view TEM image



b. A cross-sectional TEM image

Fig. 7 Observations of 256M-DRAM TEG pattern defects

Specimen: 256M-DRAM TEG of a shallow trench isolation
Instrument: HF-2200
Accelerating voltage: 200 kV

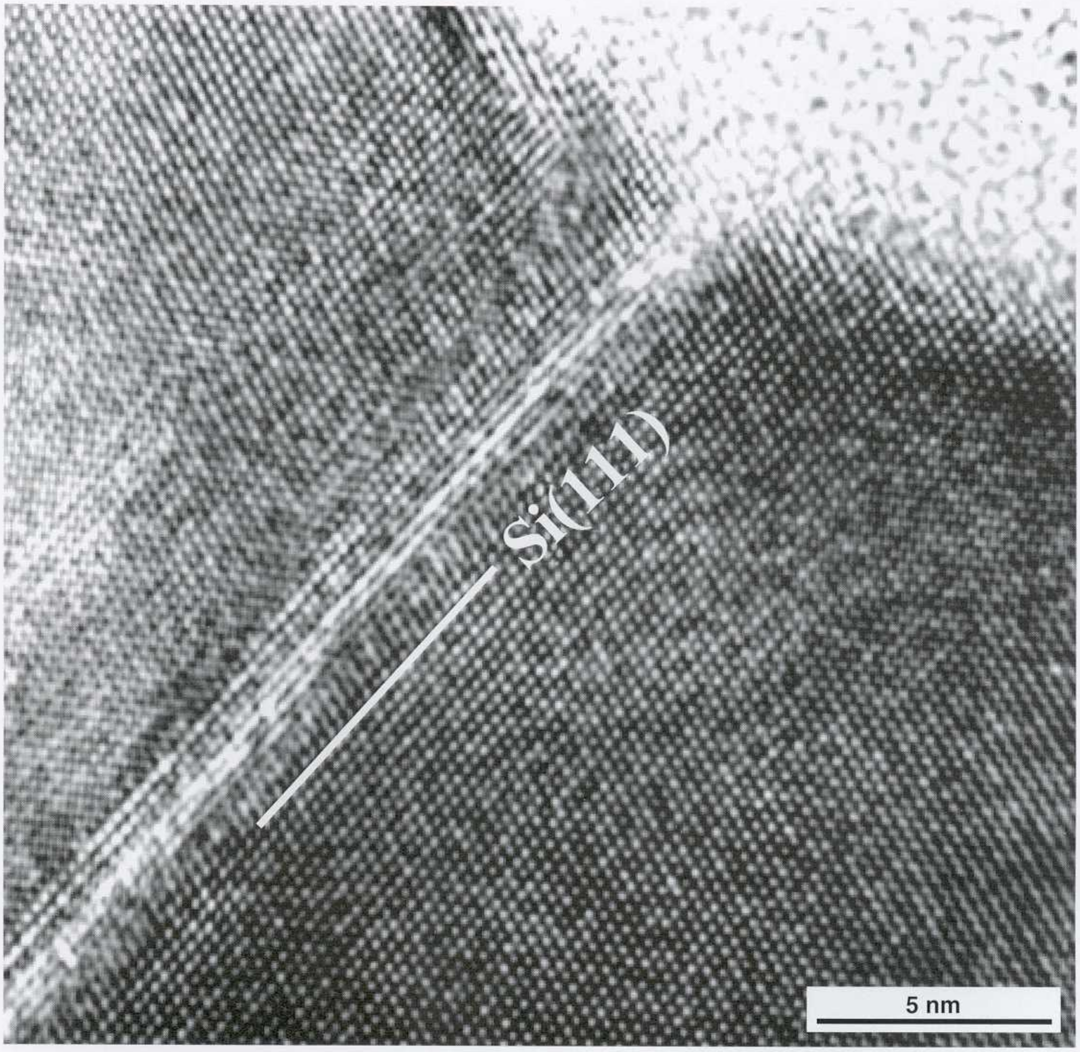


Fig. 8 A high resolution image of a 256M-DRAM TEG pattern defect

Specimen: 256M-DRAM TEG of a shallow trench isolation
Instrument: HF-2200
Accelerating voltage: 200 kV

4. CLOSING

We have reported on 3-dimensional structure analysis and applications for failure analysis of semiconductor devices using the FIB micro-sampling technique. This technique allows site-specific thin specimen preparation of defect areas and in a clean environment and it permits high resolution structure analysis on an atomic scale. This technique can be applied not only for semiconductor devices but also ceramics, metals, polymers and almost all kinds of solid materials. We trust that it will be a very useful technique for materials characterization in various fields of science and industry.

Instruments, Hitachi, Ltd. *For further information, please contact your nearest sales representative.*
Tokyo, Japan
www.hitachi.co.jp/Div/keisokuki

Printed in Japan (H) **EX-E870-7** 2001.8