HITACHI SCIENTIFIC INSTRUMENT
TECHNICAL DATA
TEM

SHEET NO. 103

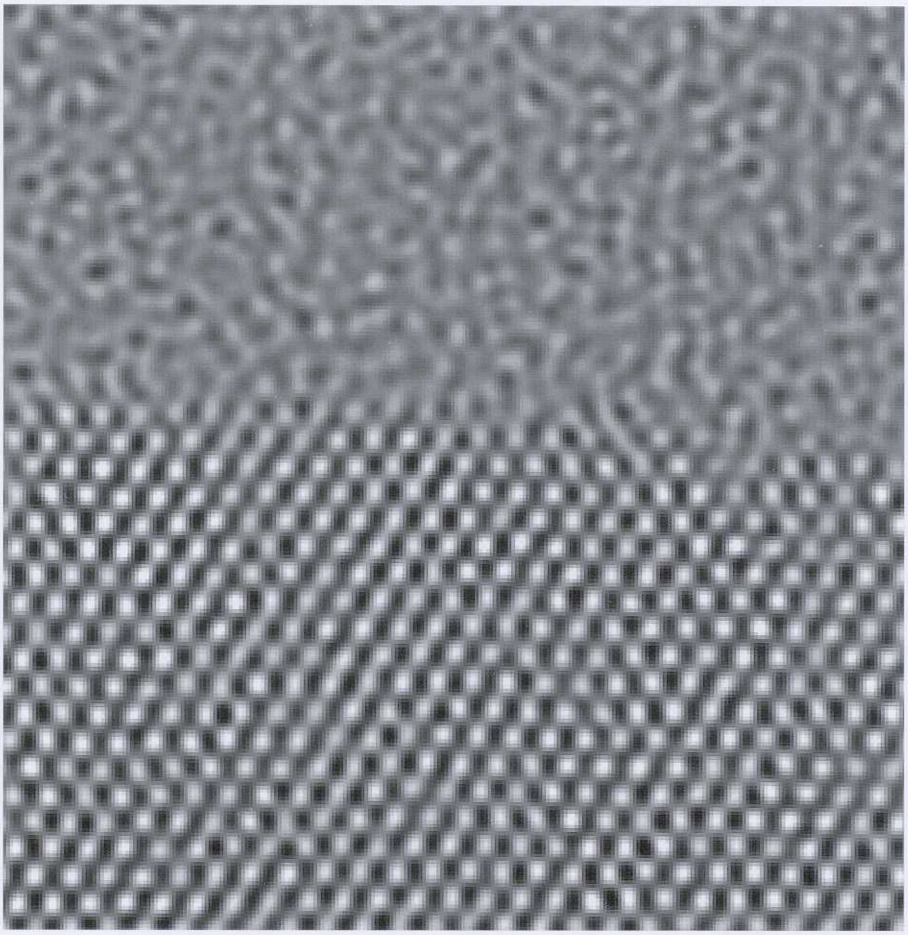
SUBJECT: 64M-DRAM VIEWED USING THE HD-2000 — FROM SPECIMEN PREPARATION TO NANO-AREA ANALYSIS

INSTRUMENT: HD-2000 AND FB-2000A

CONTENTS:

1. INTRODUCTION

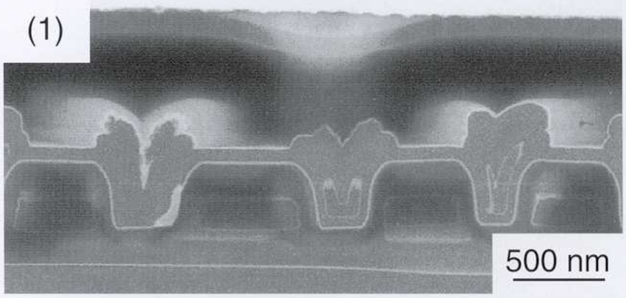
We report on a series of initial applications of the HD-2000 and the FB-2000A using a 64M-DRAM specimen from preparation to high resolution microscopy as well as elemental microanalysis.



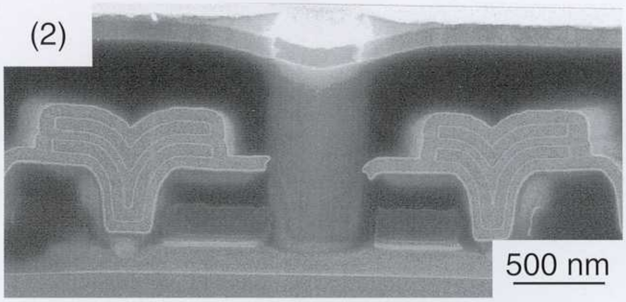
HITACHI

2. SPECIMEN THINNING PROCESS

The HD-2000 and the FB-2000A operate with a compatible specimen holder without repositioning the specimen once mounted on the holder. This design allows specimen preparation of the area of interest at a high positional accuracy or site-specific preparation is possible. Below is a series of specimen thinning processes using the compatible specimen holder.

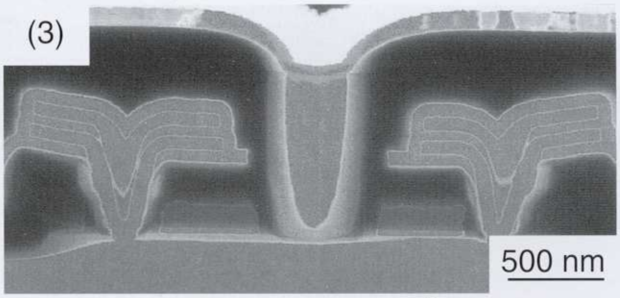


(1) When the specimen is thinned at about a few microns, it is observed in high voltage secondary electron mode. It is possible to view an Si-device specimen at a depth of about 1 micron. This image is convenient and useful for operators to determine if additional milling is required. Here, we can see plug-walls in a foggy condition.

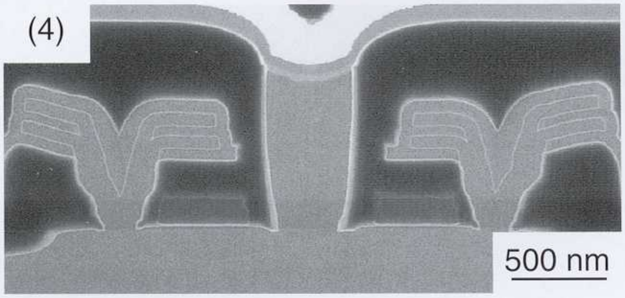


(2) This is a picture after additional milling of about 0.3 microns. A contact plug is visible better now. Here, we do not see bit-lines any more.

(3) This is a picture after additional milling of about 0.1 microns. A part of the contact plug is exposed on the surface.



(4) Now, we have reached the center of the contact plug. Further milling at the back of this specimen will allow a thin section of the true center of the contact plug.



3. OBSERVATION OF THINNED SPECIMENS

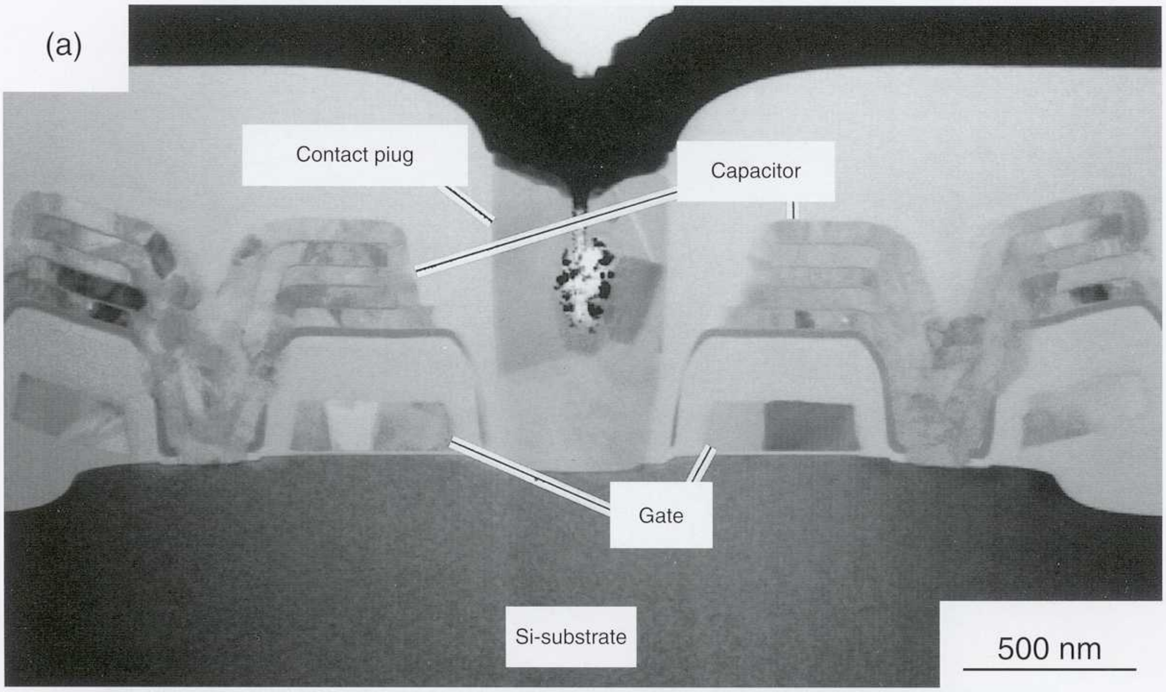
Shown below are the HD-2000 microscope images of thinned specimens.

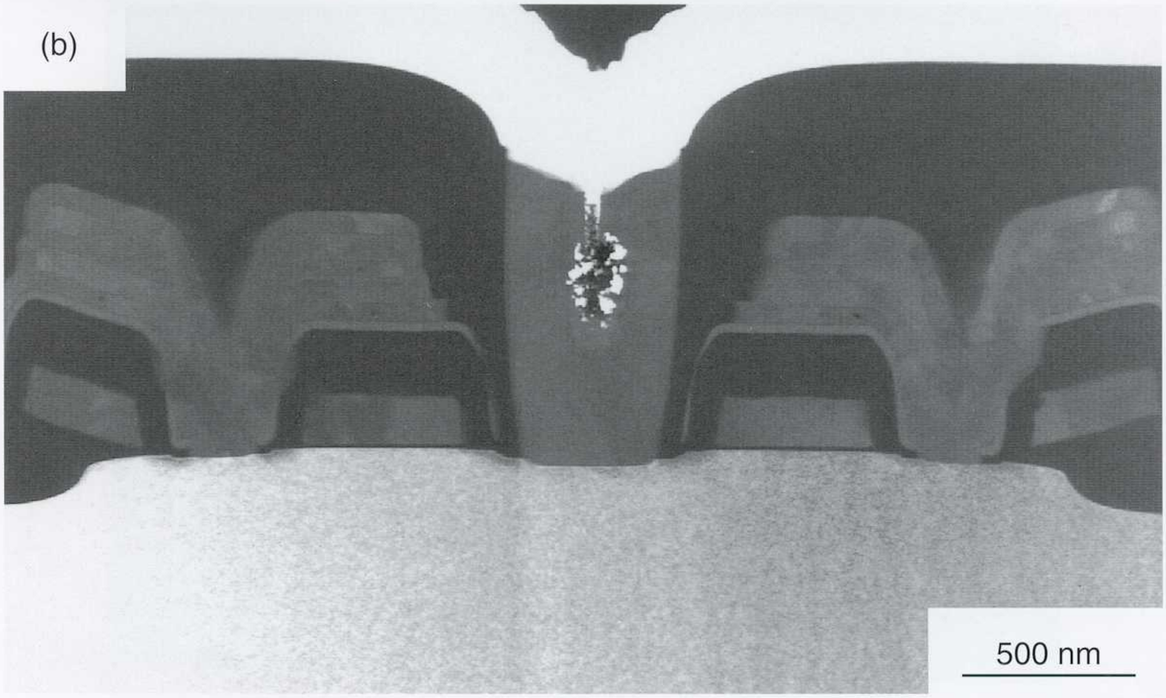
(a) TEM compatible image
(Phase contrast image)

This is an image recorded with the same operating conditions as the bright field image of TEMs. Here, we can see overall structures, shapes and dimensions of poly-Si crystal grains of the capacitor very clearly.

(b) Z-contrast image

This image corresponds to the dark field image of TEMs. The image contrast reflects mean atomic numbers of materials which compose the specimen.



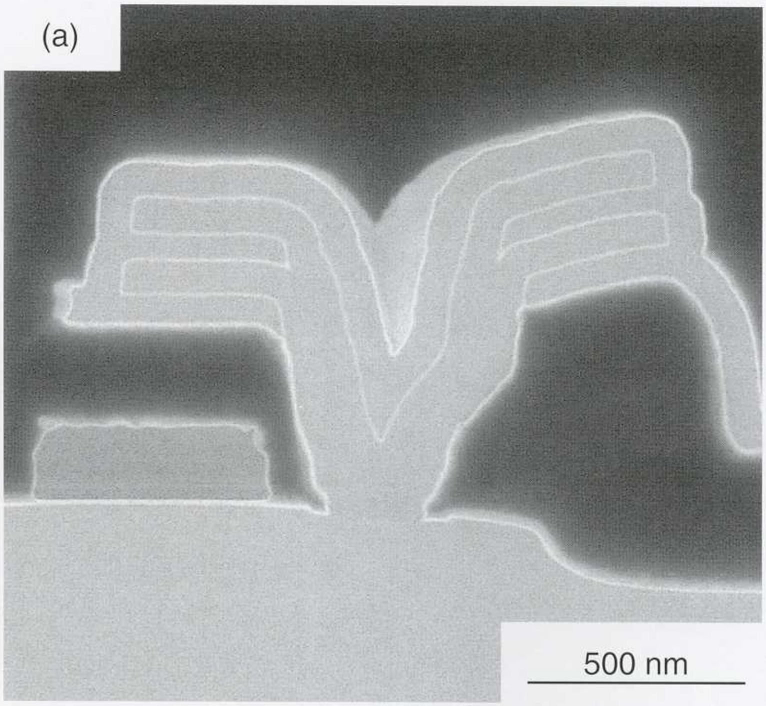


4. OBSERVATION OF CAPACITORS

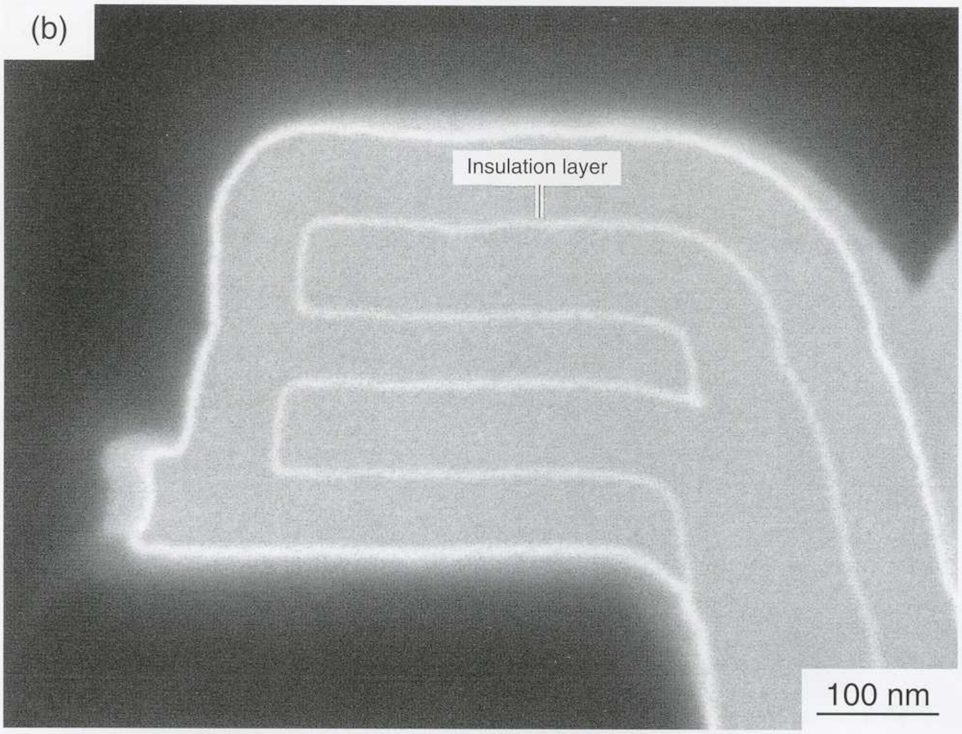
4.1 Secondary electron image

Capacitors are composed of poly-Si and insulation layers of SiN, SiO, etc. High voltage secondary electron image is very useful for observation of overall insulation layer structures. (a) is a low magnification image. (b) is a relatively high magnification image of the same specimen.

(a)



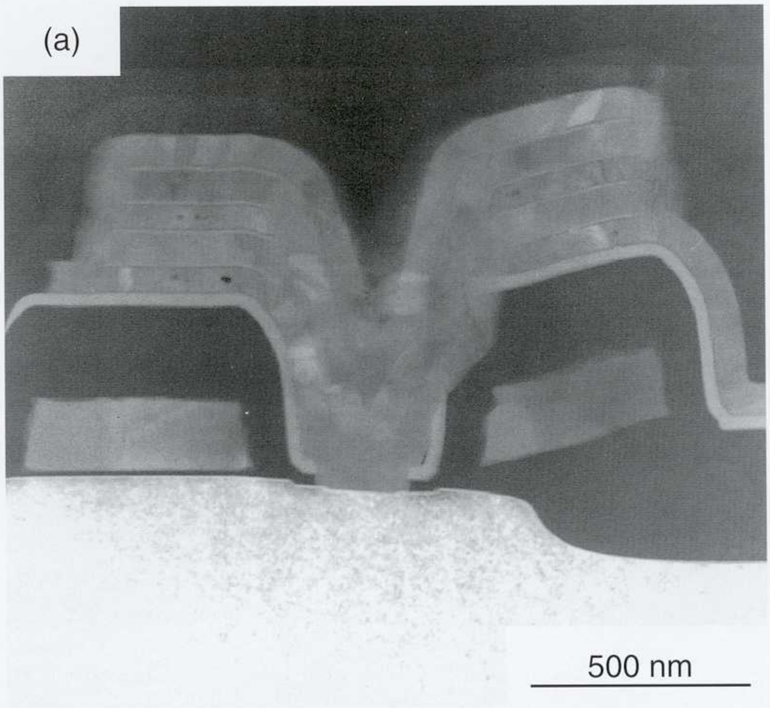
(b)

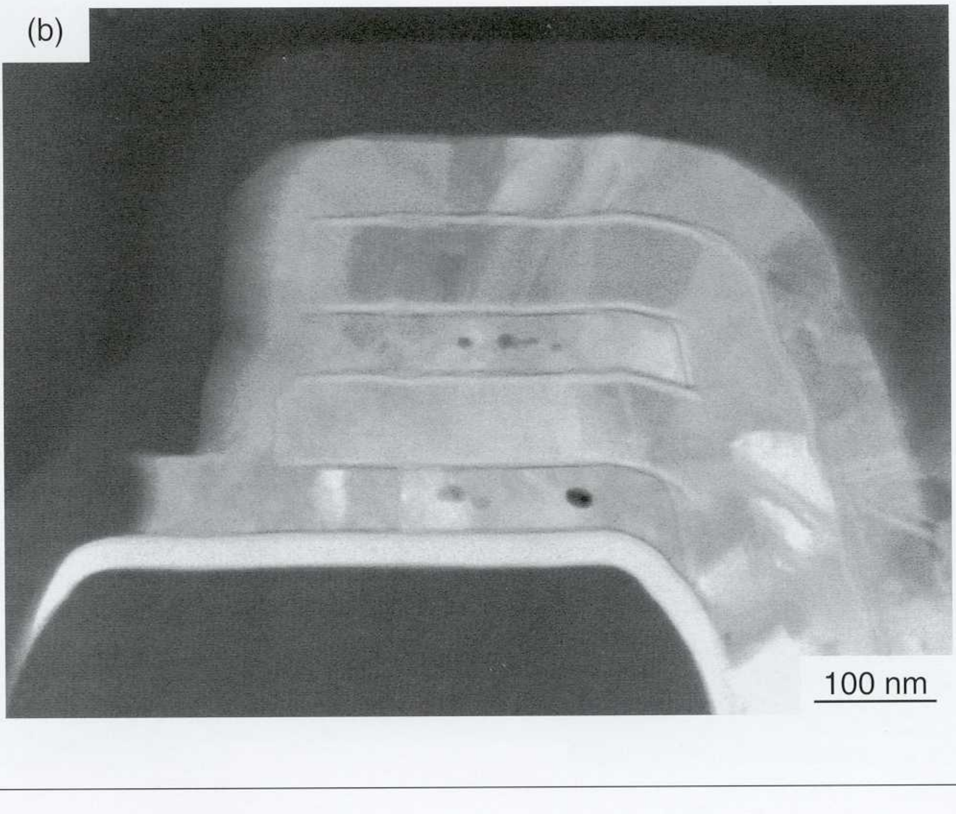


4.2 Z-contrast image

The Z-contrast image is useful for observation of insulation layers such as SiN and SiO. It is particularly useful for telling one layer from the other. Here, you can see SiO in dark contrast and SiN in bright contrast and both layers are clearly separated from poly-Si.

(a) is a low magnification image and (b) is a relatively high magnification image.

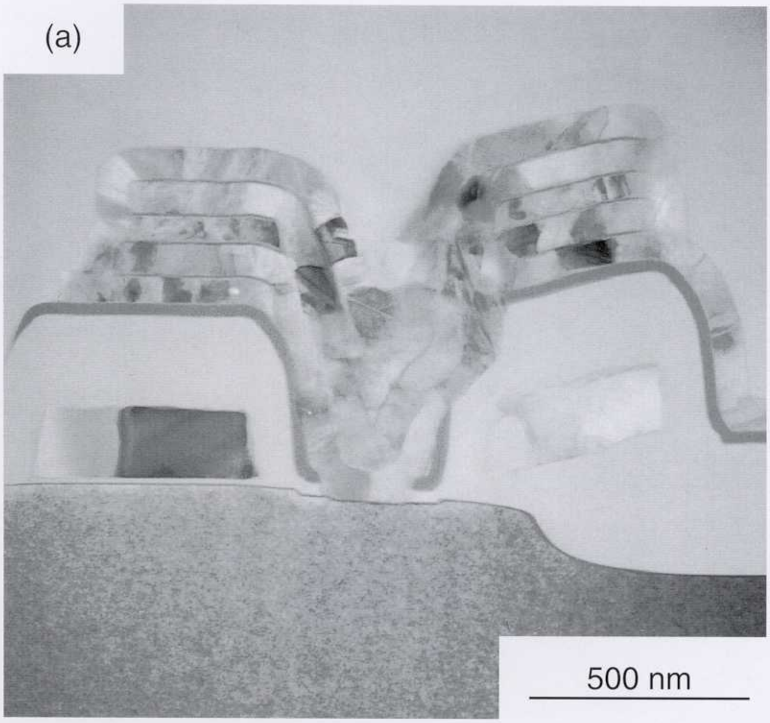




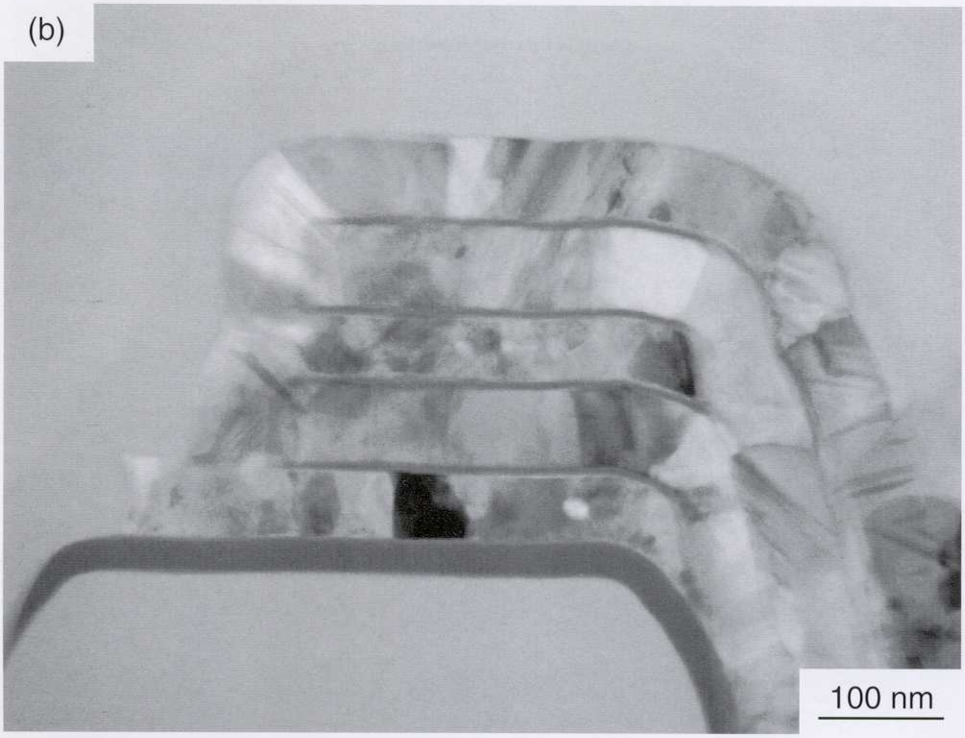
4.3 TEM compatible image (Phase-contrast image)

For observation of shapes of each crystal grain of poly-Si of capacitors, the phase-contrast image is very useful. Crystal grains have different orientations so that they look dark or bright depending on each grain. In the phase-contrast image, these grains are clearly visible as shown here. (a) is a low magnification image and (b) is a relatively high magnification image of the same specimen.

(a)

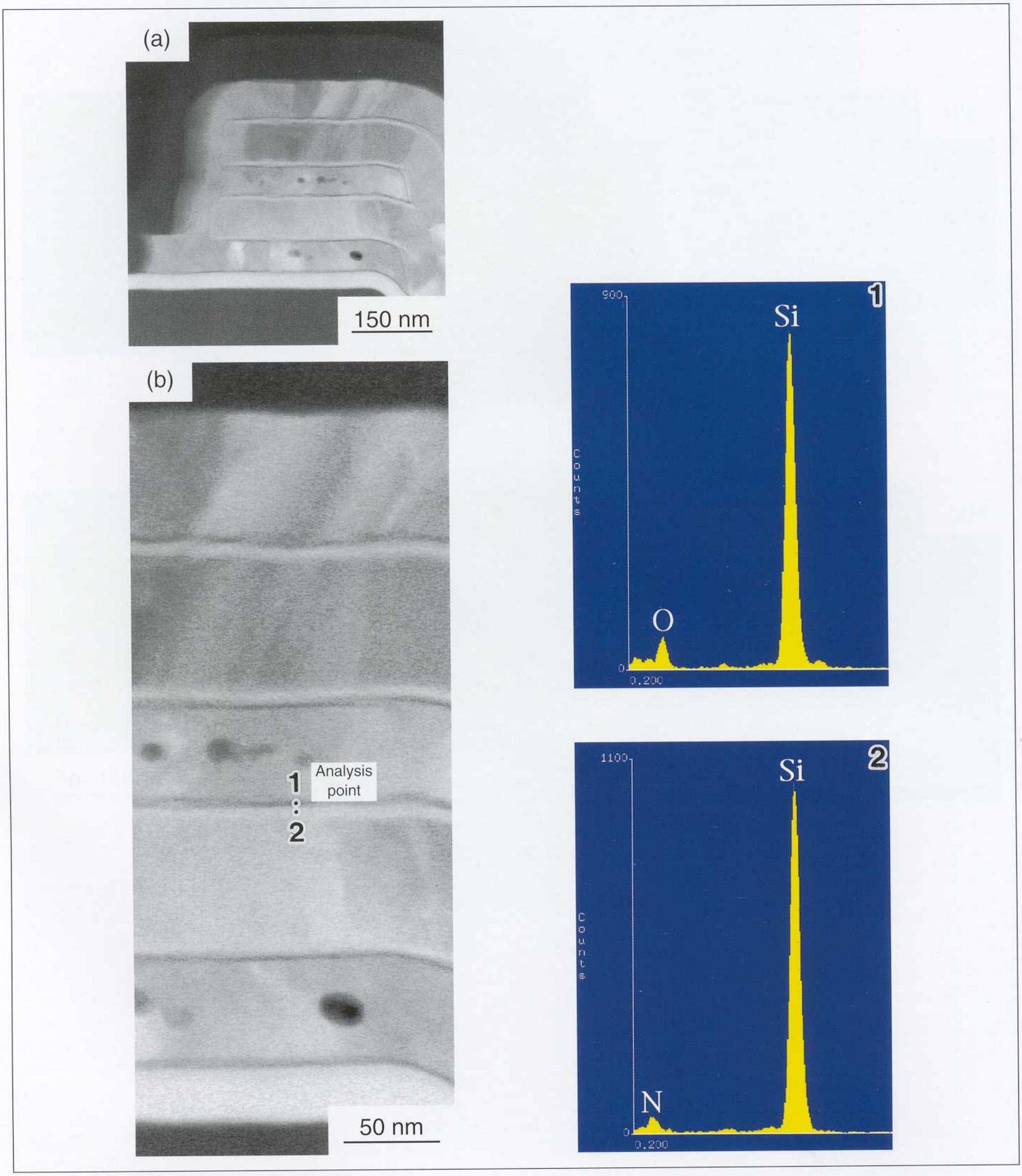


(b)



4.4 Point analysis using EDX spectrometer

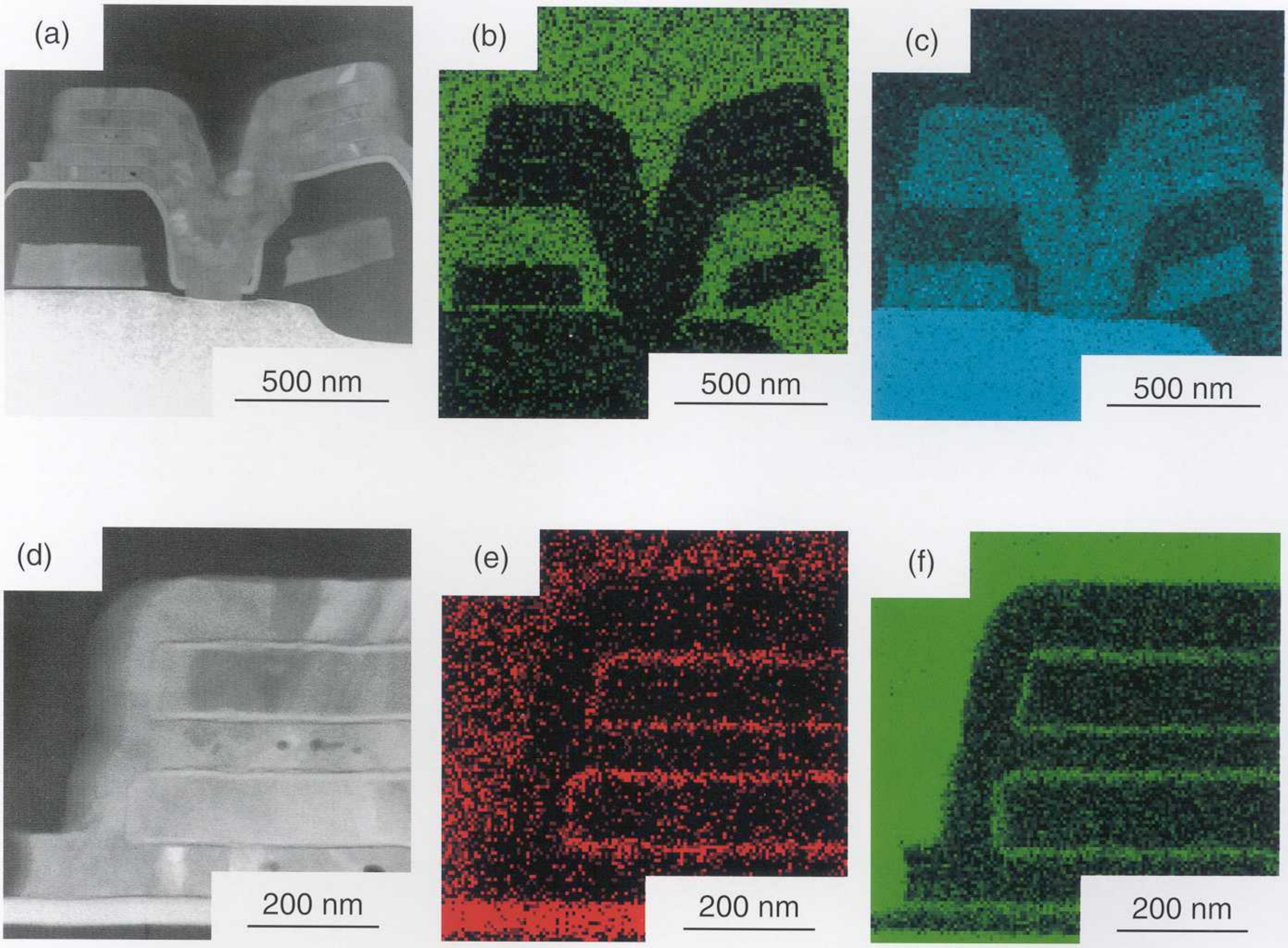
Compositions of insulation layers of capacitor areas are analyzed using the EDX spectrometer. Oxide and nitride layers are clearly separated here. (a) is a low magnification image and (b) is a high magnification image of the same specimen. (b) shows the analytical points 1 and 2. X-ray spectra 1 and 2 correspond to these analytical points.



4.5 X-ray mapping

Shown below are Z-contrast and X-ray mapping images of capacitor areas.

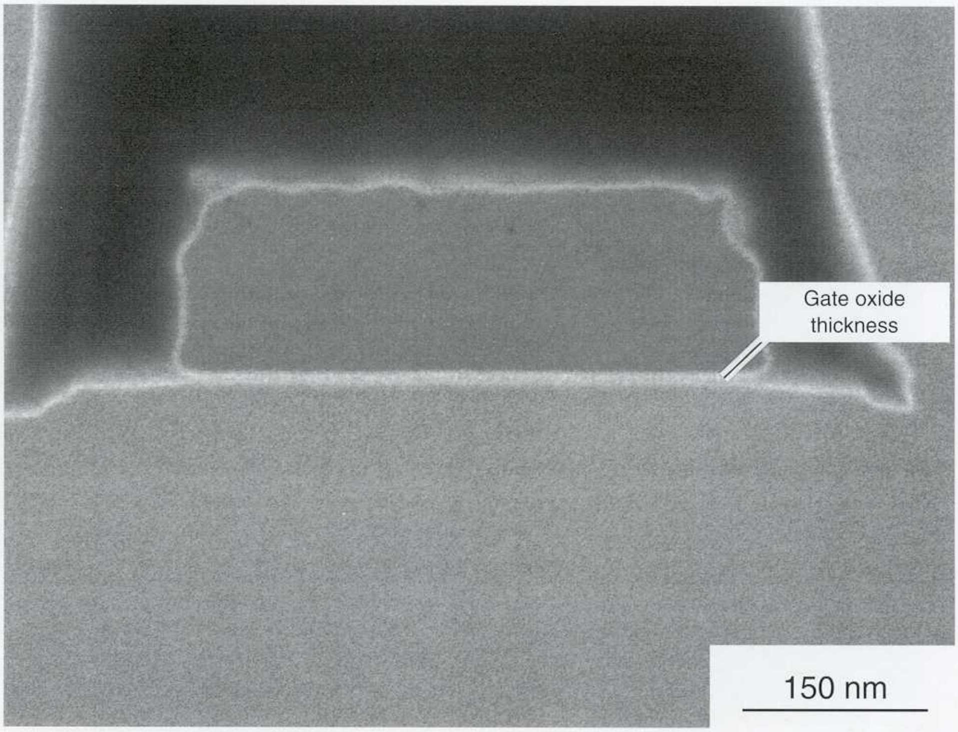
(a) Z-contrast image
(b) Oxygen mapping image
(c) Si-mapping image
(d) Z-contrast image at a high magnification
(e) Nitrogen mapping image at a high magnification
(f) Oxygen mapping image



5. OBSERVATION OF GATE AREAS

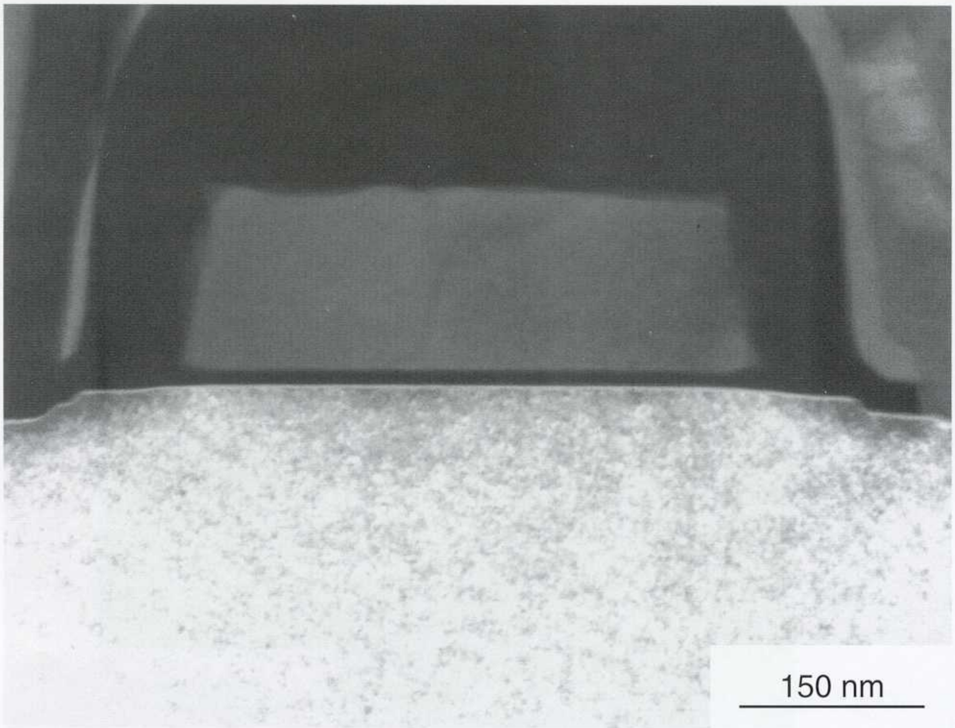
5.1 Secondary electron image

The shape and thickness of gate areas are clearly visible. The gate oxide thickness of about 10 nm is also observed here.



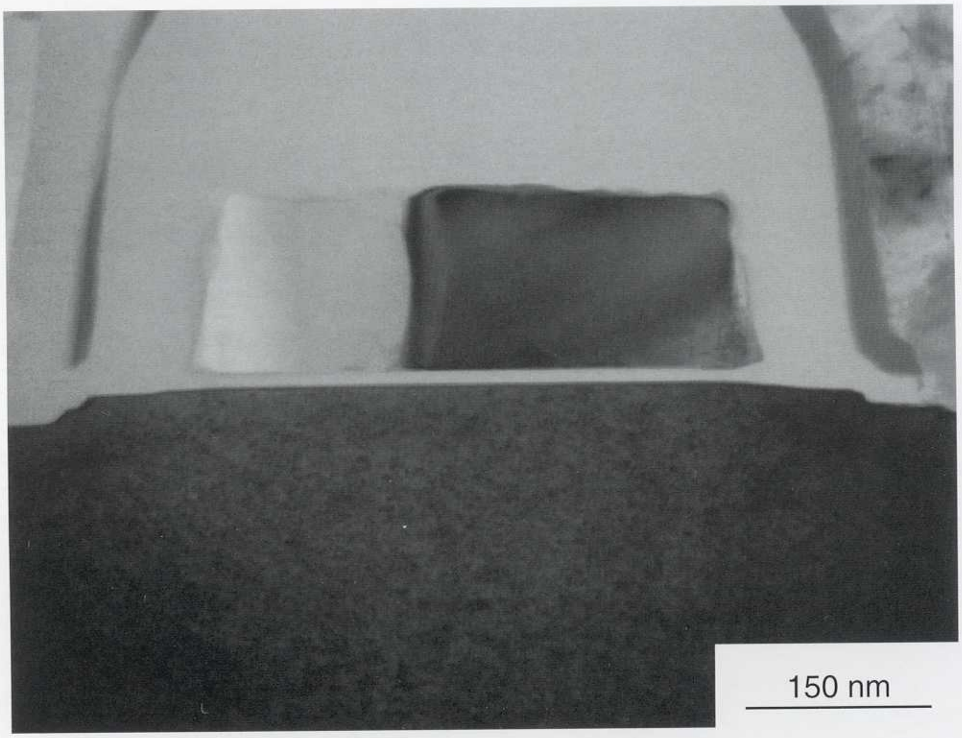
5.2 Z-contrast image

The gate oxide layer is made visible by mean atomic number contrast of the gate and surrounding oxide layer (SiO).



5.3 TEM compatible image (Phase-contrast image)

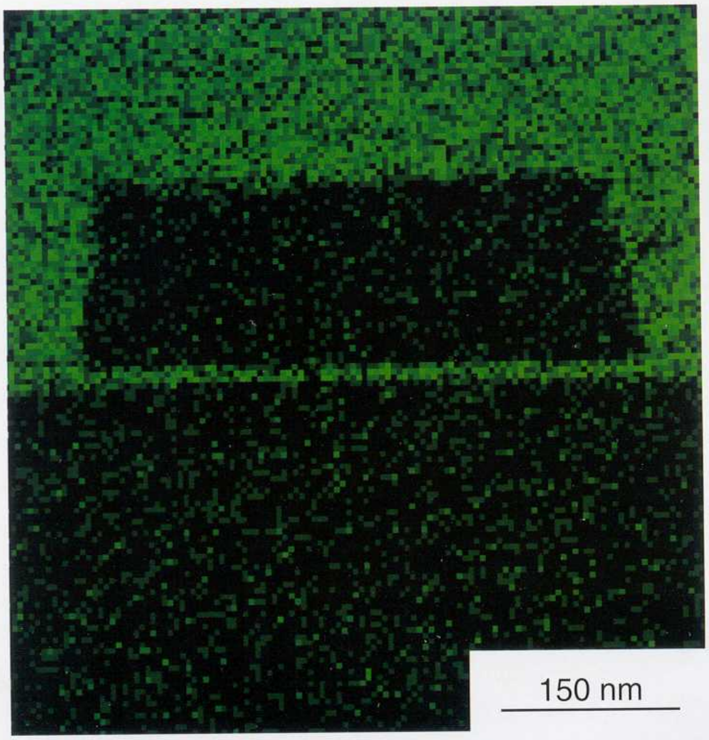
The shape and dimensions of crystal grains of poly-Si of the gate are clearly shown here.



5.4 X-ray mapping

This is an oxygen (O-k) mapping image.

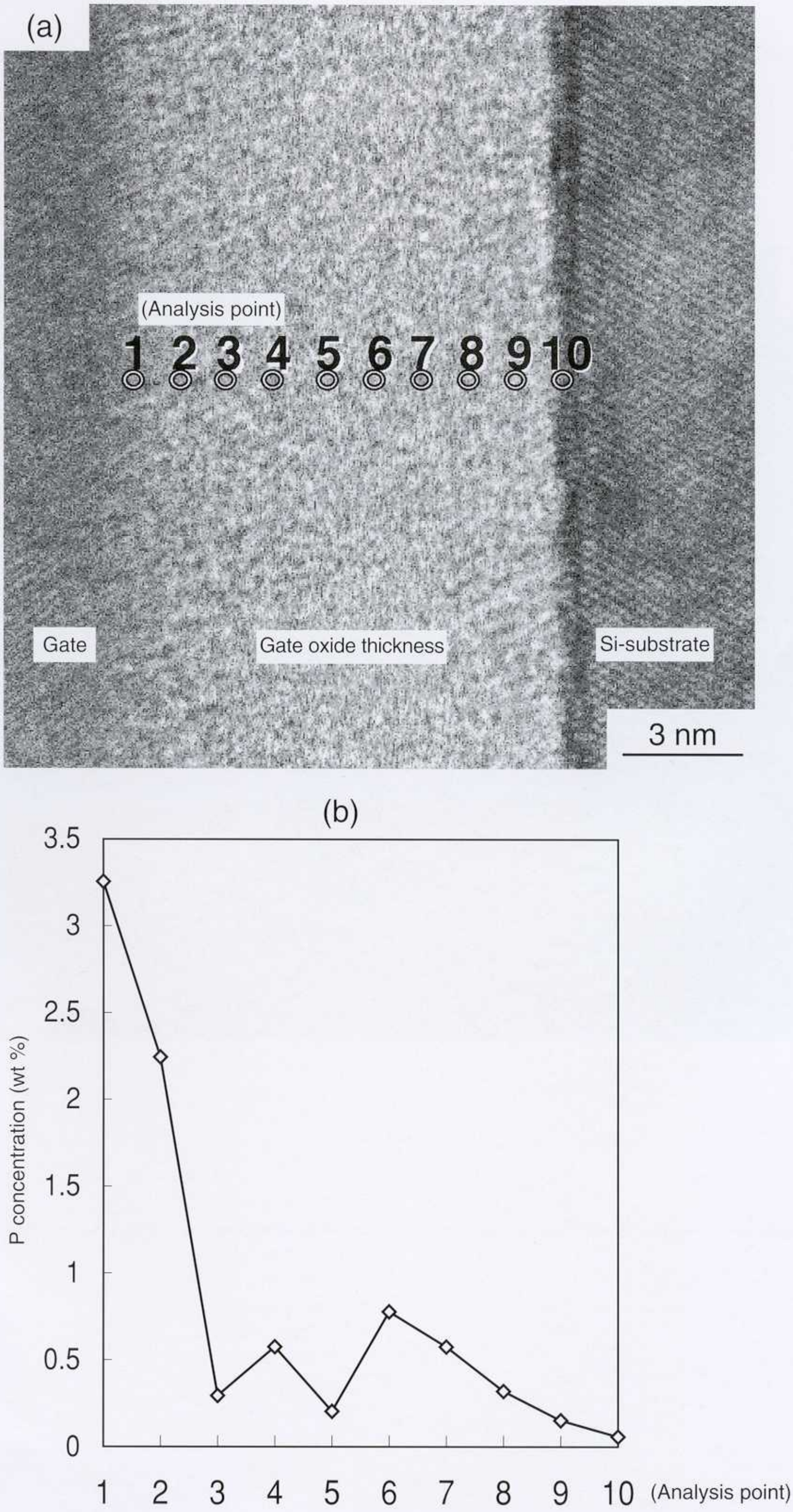
The oxide layer which surrounds the gate at a thickness of about 10 nm is seen clearly.



6. PHASE CONTRAST IMAGE AT HIGH MAGNIFICATIONS & EDX ANALYSIS

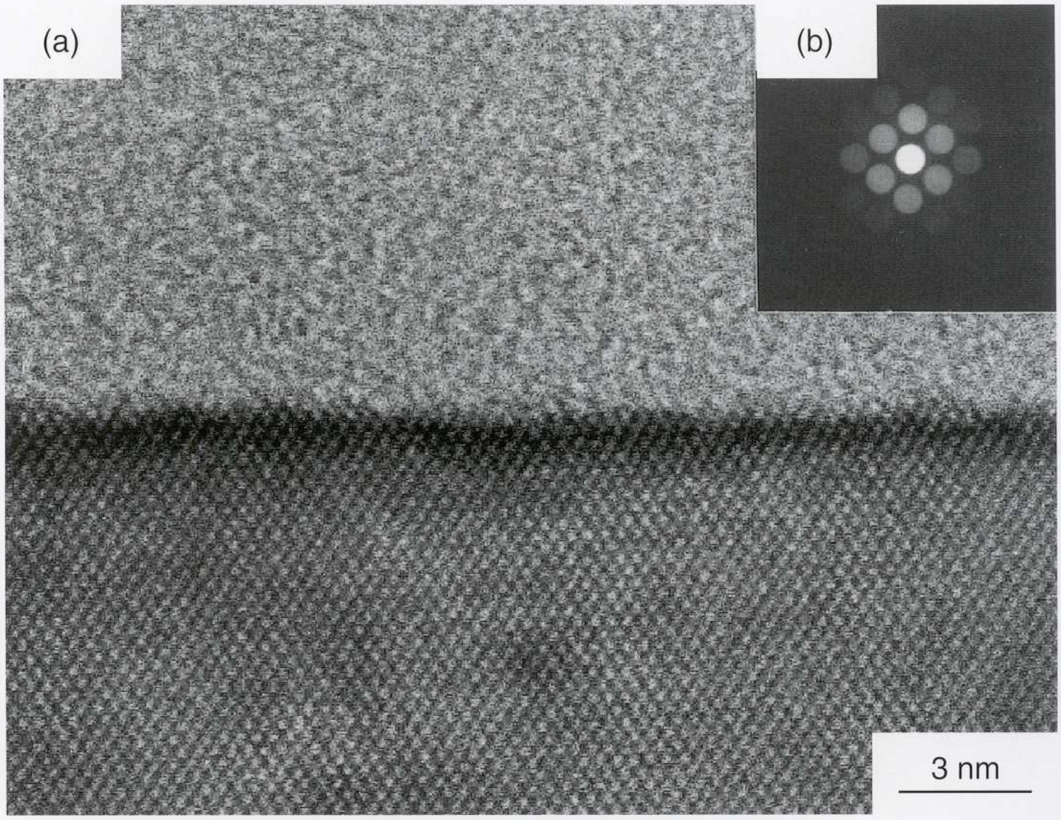
(a) This is a high resolution microscope image of a gate oxide layer. You can see crystal lattice spacings of 0.31 nm of Si(111) of silicon substrate very clearly. Numbers shown on the image are points on which EDX analysis is performed using a very fine probe of 0.5 nm.

(b) This graph shows phosphor concentrations measured at 10 points on the gate oxide layer. We can see fluctuations of phosphor in the oxide layer.

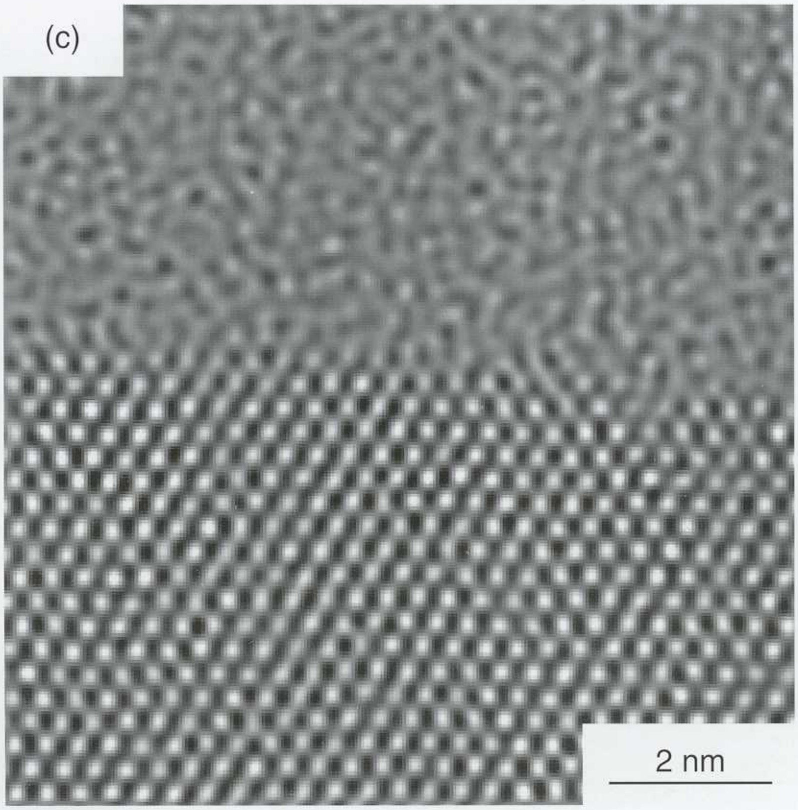


7. HIGH RESOLUTION OBSERVATION OF GATE OXIDE LAYERS AND Si-SUBSTRATE INTERFACE

(a) This is a high resolution image of the gate oxide layer and Si-substrate interface. It shows crystal lattice spacings of 0.31 nm of Si(111). When recording this type of crystal lattice image, it is necessary to align orientations of the specimen in diffraction mode as shown in (b).

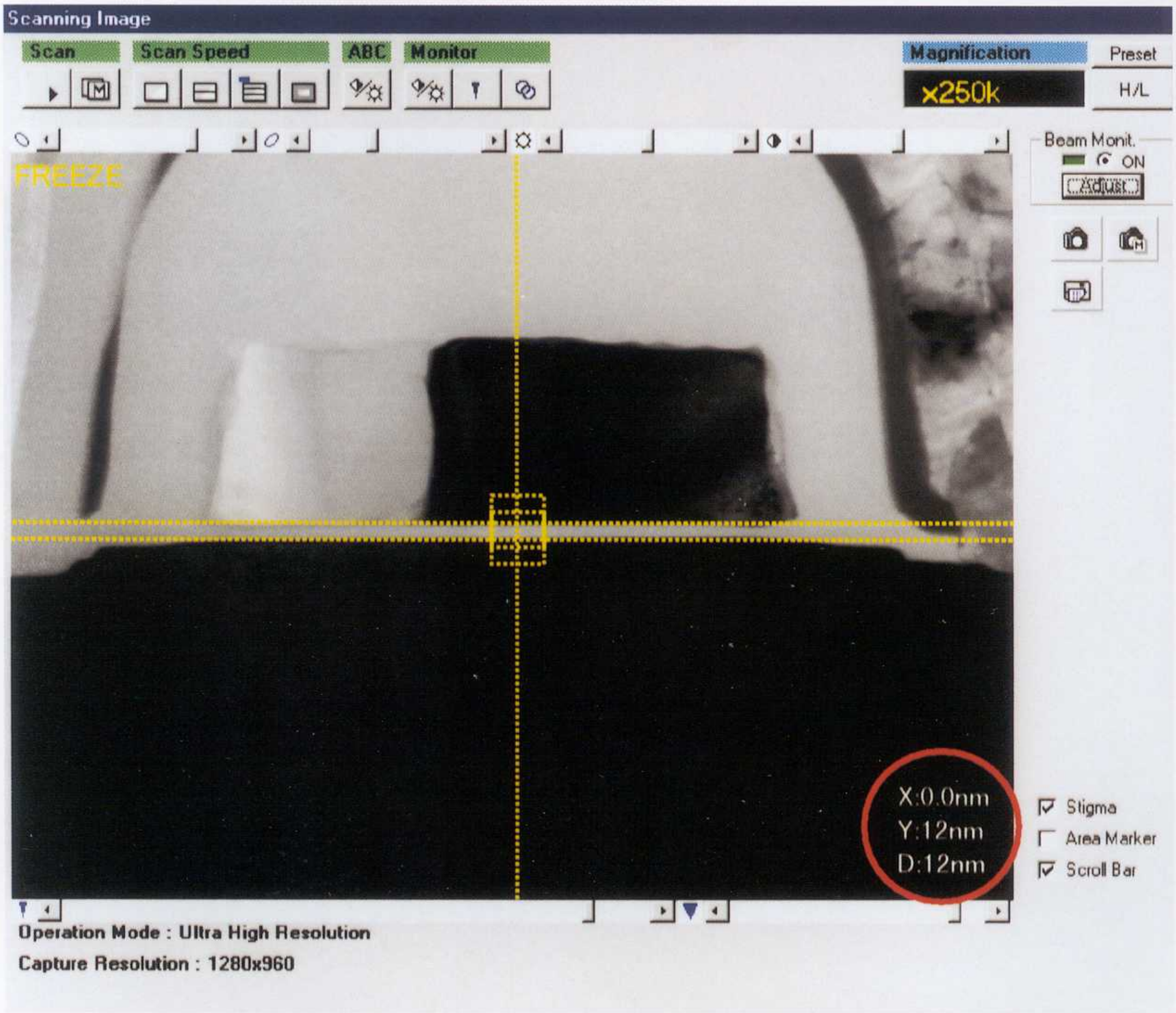


(c) This is a processed image of (a). It is used for evaluation of the roughness of interface of Si-atom. The HD-2000 produces images in a digital format so that it allows image processing on line without loss of time.



8. CD-MEASUREMENT FUNCTION

This is an example of CD-measurement of a gate oxide layer of about 12 nm wide. The CD-measurement mode allows display of measurement in three different directions; X (horizontal), Y (vertical), and D(diagonal).



Magnification ×250k

Beam Monit. ● ON

X:0.0nm
Y:12nm
D:12nm

☑ Stigma
☐ Area Marker
☑ Scroll Bar

Operation Mode : Ultra High Resolution
Capture Resolution : 1280x960

9. CLOSING

We have reported on some initial applications of the HD-2000 for semiconductor devices. The HD-2000 allows secondary electron, Z-contrast, and phase-contrast images. These three kinds of images can provide numerous information about the specimen of interest. The HD-2000 allows X-ray microanalysis at higher sensitivity of about 2.5 times the conventional TEM system so that the HD-2000 permits analysis of much smaller areas or lower concentrations. We trust that the HD-2000 will be useful for material characterizations in the leading edge of technology.