HITACHI SCIENTIFIC INSTRUMENT TECHNICAL DATA STEM

SHEET NO. 5

SUBJECT: ANALYSIS OF BARRIER METAL LAYERS OF SI-DEVICES

INSTRUMENT: THE HD-2000 ULTRA THIN FILM EVALUATION SYSTEM & GATAN DIGITAL PEELS

CONTENTS:

1. INTRODUCTION

The HD-2000 has been used for some time in the evaluation and failure analysis of electronic materials and devices. It has various imaging modes which are not available with conventional analytical TEMs. It allows accommodation of various electron detectors such as a bright field STEM detector which permits observation of crystalline specimens at high phase contrast, a dark field detector which permits observation of slight composition or density differences at high atomic number contrast, and a secondary electron detector which permits 3-dimensional observation from surface to inner structures of about a micron deep. In addition, it allows accommodation of EDX spectrometers for elemental analysis.

Analysis of barrier metal layers in Si-devices is one of the important evaluation requirements for the semiconductor industry. The barrier metal layers have been used for a long service life of devices or for protecting metal wirings from chemical reactions with corrosive gases. These layers are composed of Ti or TiN and they are required to have a uniform thickness.

X-ray analysis using EDX spectrometers is unable to tell Ti from TiN owing to a limited energy resolution. Electron energy loss spectroscopy (usually called EELS) is another good way for composition analysis. When this technique is coupled with the HD-2000 which operates with a cold field emission electron source, it allows a high energy resolution. We have employed the EELS spectrum imaging technique for analysis of barrier metal layers in Si-devices. We report here on this analysis with some results.

2. METHODS

2.1 EELS spectrum imaging

Elemental mapping and line analysis using EELS spectra available with STEM/TEM and EELS are generally called a spectrum imaging technique. This technique allows recording of EELS spectra at all specified pixel points in addition to mapping and line analyses. It permits chemical compositions and their bonding information by fine structure analysis using EELS spectra at each pixel.

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2.2 Instruments

Fig. 1 shows the HD-2000 with Gatan's digital PEELS. The spectrometer is mounted below the column of the HD-2000. The power supply, DigiScan unit and EELS control PC are located on the display/control table of the HD-2000.

2.3 Specimen

An Si-device was used. The barrier metal layer is composed of TiN, Ti and TiO_2 layers. It is important to measure thickness of TiN and Ti layers. For specimen preparation, we have used the FB-2000A focused ion beam system operated at 30 kV.

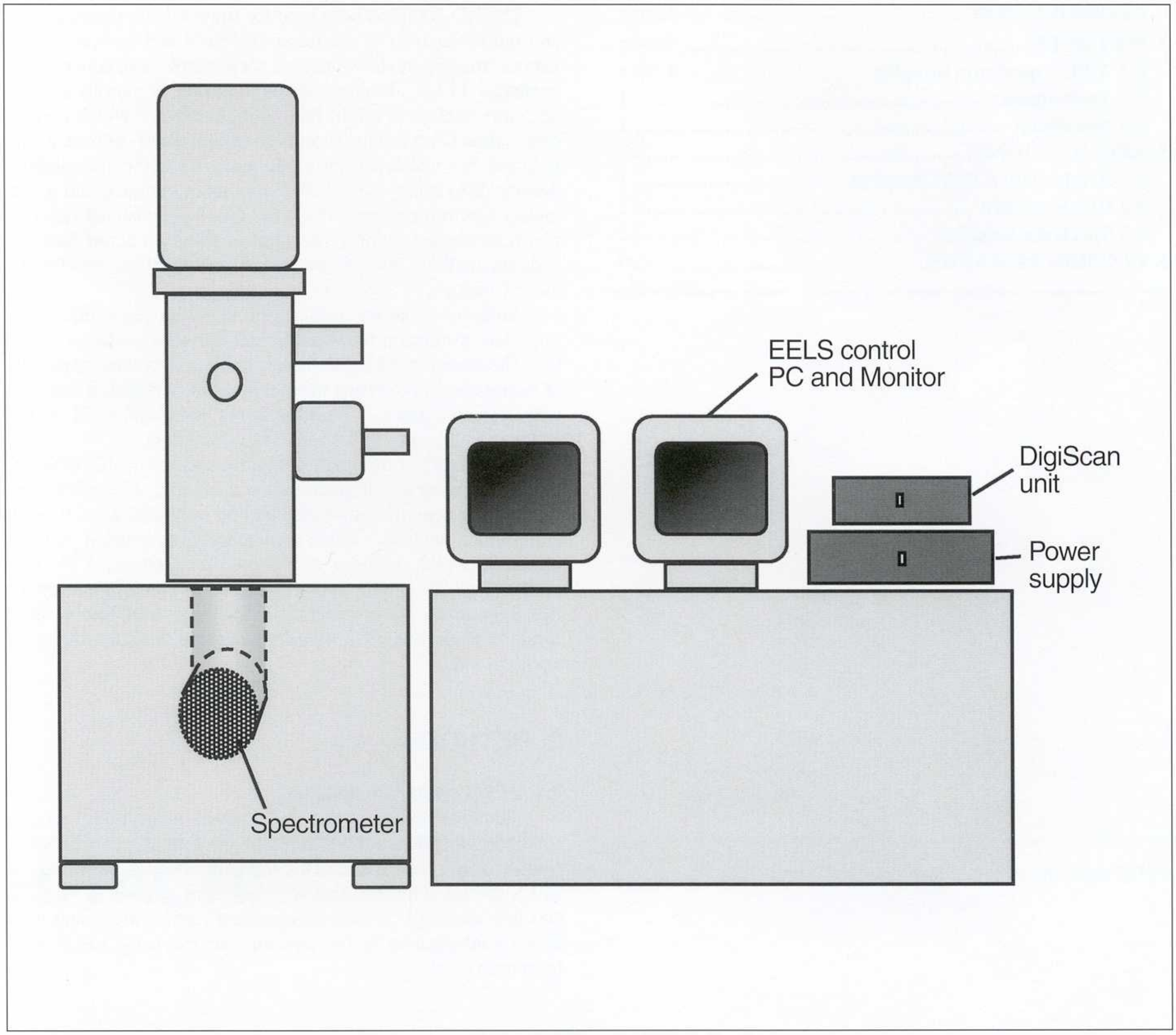

Fig. 1 The HD-2000 with EELS.

3. APPLICATIONS

3.1 Bright field STEM imaging

Fig. 2 shows a bright field STEM image of a barrier metal layer recorded at 200 kV using the HD-2000. A high density amorphous layer of about 10 nm on SiO_2 layer on the Si-substrate is clearly observed. Crystal structures of about 25 nm thick are seen both horizontally and vertically on the amorphous layer.

3.2 EELS spectrum

Fig. 3 shows a bright field STEM image with 3 analysis points (a) and EELS spectra (b). This analysis tells us that the top layer (1) is TiN, the middle layer (2) Ti and the bottom layer (3) TiO_2 on SiO_2.

3.3 Spectrum imaging

Fig. 4 shows a bright field STEM image (a) and a spectrum image (b). The spectrum image shows measurement distance vertically and energy horizontally. The distance (A-A') is 130 nm. Point A is about the boundary of SiO_2 and point A' is about the boundary of W-deposition layer. The measurement energy range is 320 ~ 620 eV.

The Ti-L peak rises rapidly at about 17 nm from point A and the O-K peak changes its shape accordingly. The O-K peak disappears at about 28 nm from point A and the N-K peak rises at about 55 nm. From these results, we can see that TiO_2 and Ti layers are 11 nm and 27 nm thick respectively and that the other layer is TiN.

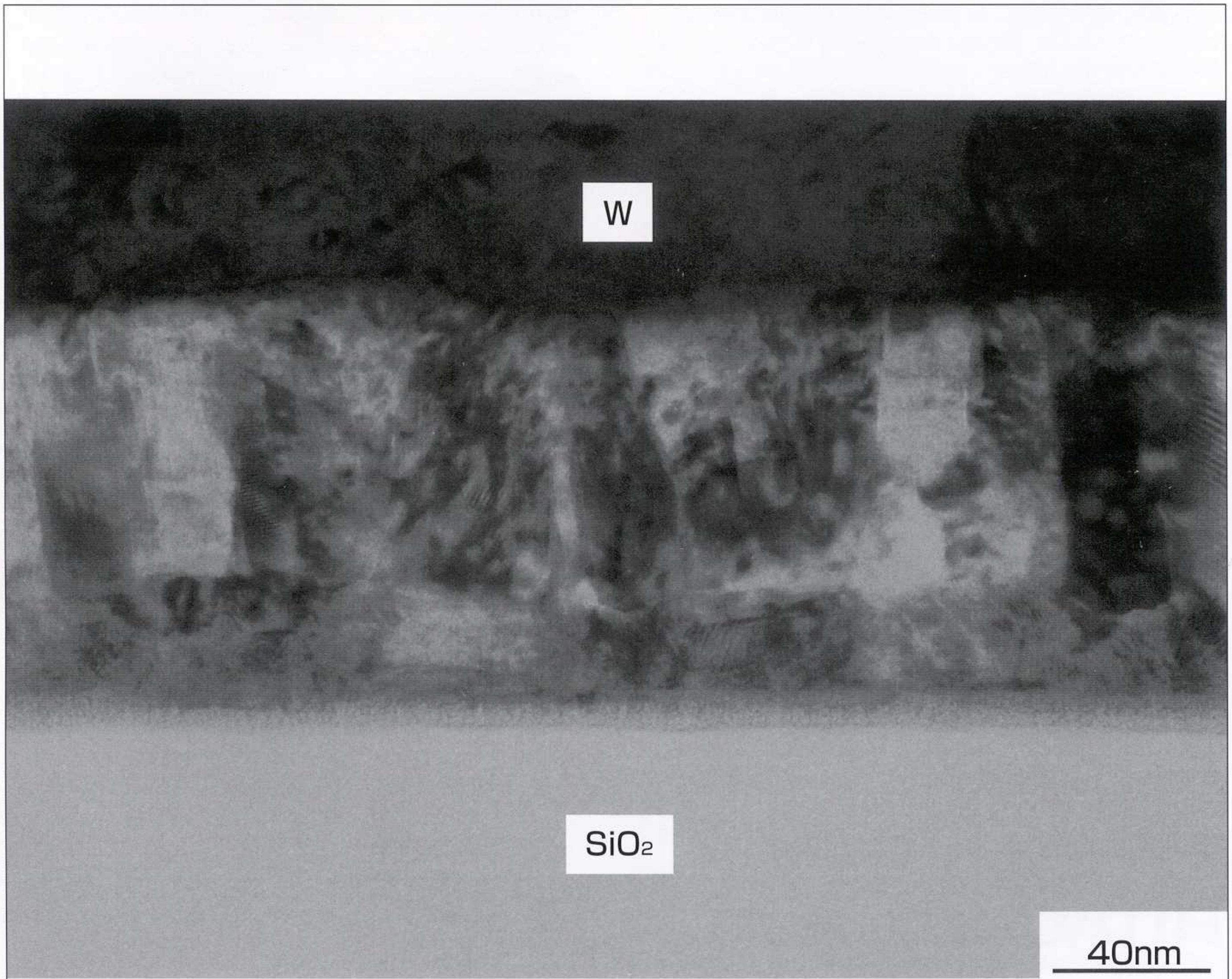

Fig. 2 Bright field STEM image of a barrier metal layer

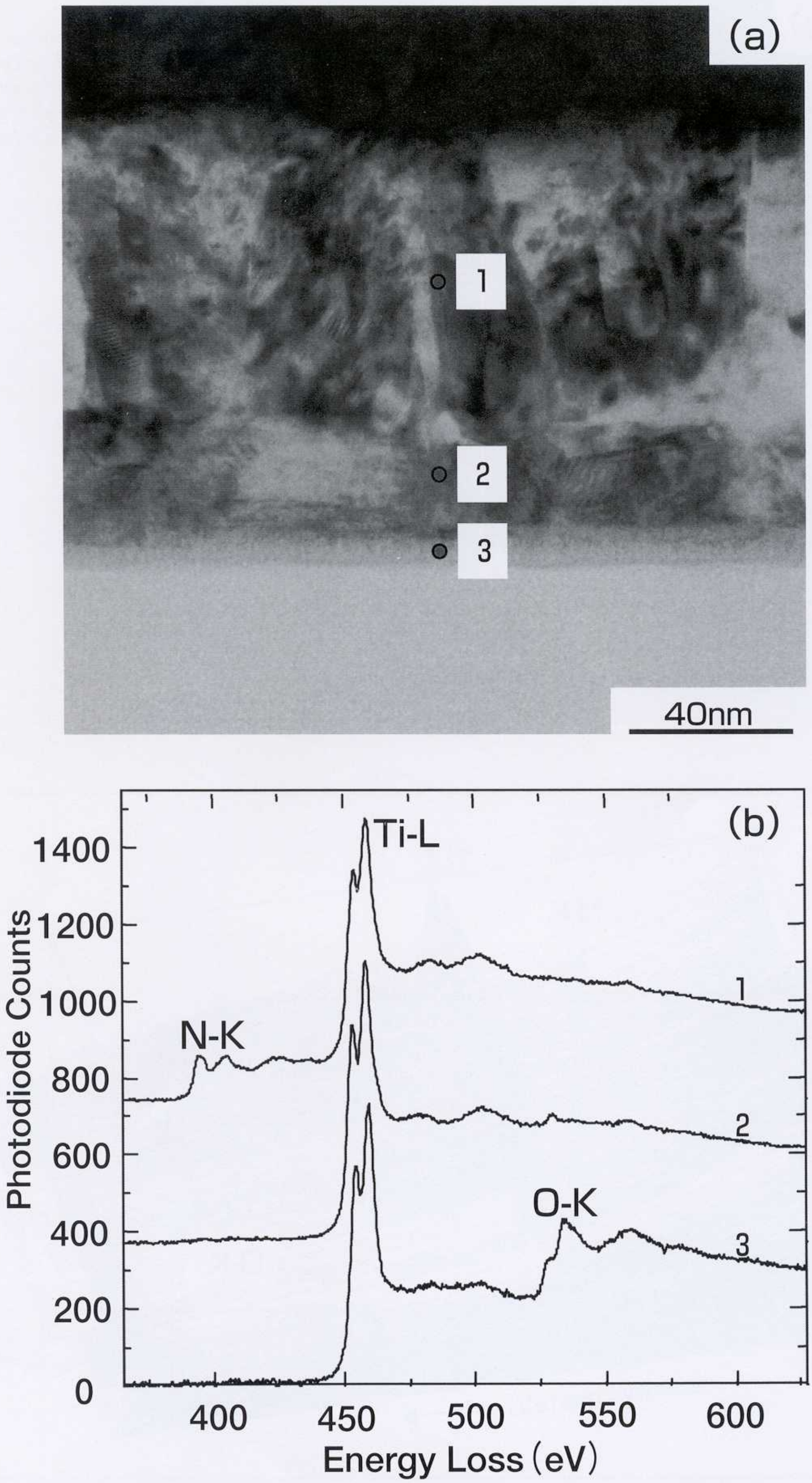

Fig. 3 Bright field STEM image of an analysis area (a) and point analysis results by EELS (b)

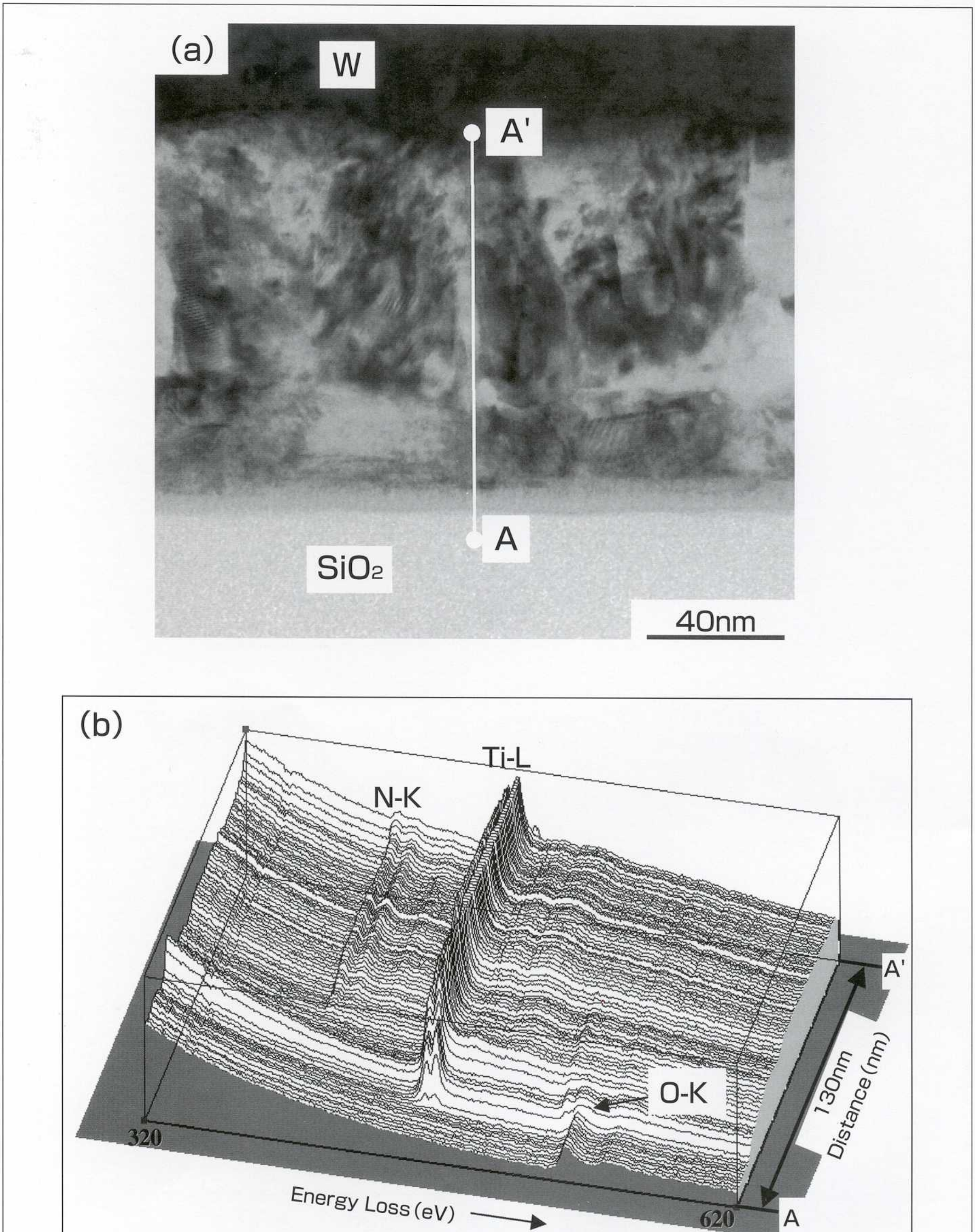

Fig. 4 Bright field STEM image of an analysis area (a) and EELS spectrum image (b)

4. CLOSING REMARKS

We have reported on analysis of barrier metal layers using the HD-2000 with EELS. Characteristic X-rays of Ti-L and N-K have similar energies so that they are difficult to separate using EDX mapping technique. By using the spectrum imaging technique, which takes advantage of transmitted electrons through the specimen, we were able to observe the two layers clearly. This technique will be useful for mapping of various materials such as WSi, Si, and other advanced compounds which are difficult for EDX spectrometers.

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For further information, please contact your nearest sales representative.

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