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Ultra-Fast Mapping of a Semiconductor Sample with Low Accelerating Voltage at High Magnification

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Key Words

- **Bulk Sample**
- **EDS**
- **Peak Overlaps**
- **Quantitative Mapping**
- **Semiconductor**

Introduction

Energy Dispersive Spectroscopy (EDS) mapping at low accelerating voltage can produce high spatial resolution data but its long acquisition time can be a problem due to the severe decrease in the X-ray generation from the sample.

The advent of Schottky FESEM which produces a high beam current at low accelerating voltage makes it possible to acquire high magnification maps in a relatively short time. For this type of acquisition, a high-performance EDS detector and analyzer are also necessary.

The Thermo Scientific NORAN System 7 EDS analyzer used in cooperation with Thermo Scientific UltraDry silicon-drift detector provides the highest performance EDS system in existence.

In this experiment, spectral imaging X-ray map data was collected for just one minute at 4kV at a magnification of 10,000X using a Schottky FESEM, UltraDry SDD detector, and an NORAN System 7 analyzer.

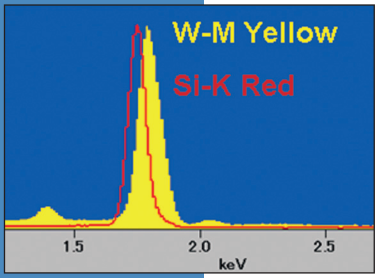
Acquisition Conditions

Sample:	Semiconductor device in cross-section
FESEM:	JEOL JSM-7600F
EDS Analyzer:	NORAN System 7
EDS Detector:	UltraDry 30 mm^2
Accelerating Voltage:	4 kV
Probe Current:	20 nA
Magnification:	10,000X
Mapping Resolution:	256 x 192
Acquisition Time:	6 frames x 10 sec/frame
Detects Rate:	82,000 cps
Stores Rate:	58,000 cps
Dead Time:	29%

Overlapping Elemental Peaks

The first result to note from the net-count maps is the very low number of X-rays actually collected in each map (value in the upper right of each map figure). In the displayed maps, C has the greatest number of counts at 72.

The EDS peaks of Si-K and W-M overlap severely as shown in the picture at left. When conventional EDS peak-count maps are produced, X-ray count maps of the specified energy regions of these overlapped peaks produce very similar Si and W maps. A similar problem can exist for other element-lines, for instance O-K and Ti-L. From these displays, it is difficult to determine if the maps truly represent the distribution of elements within the sample.



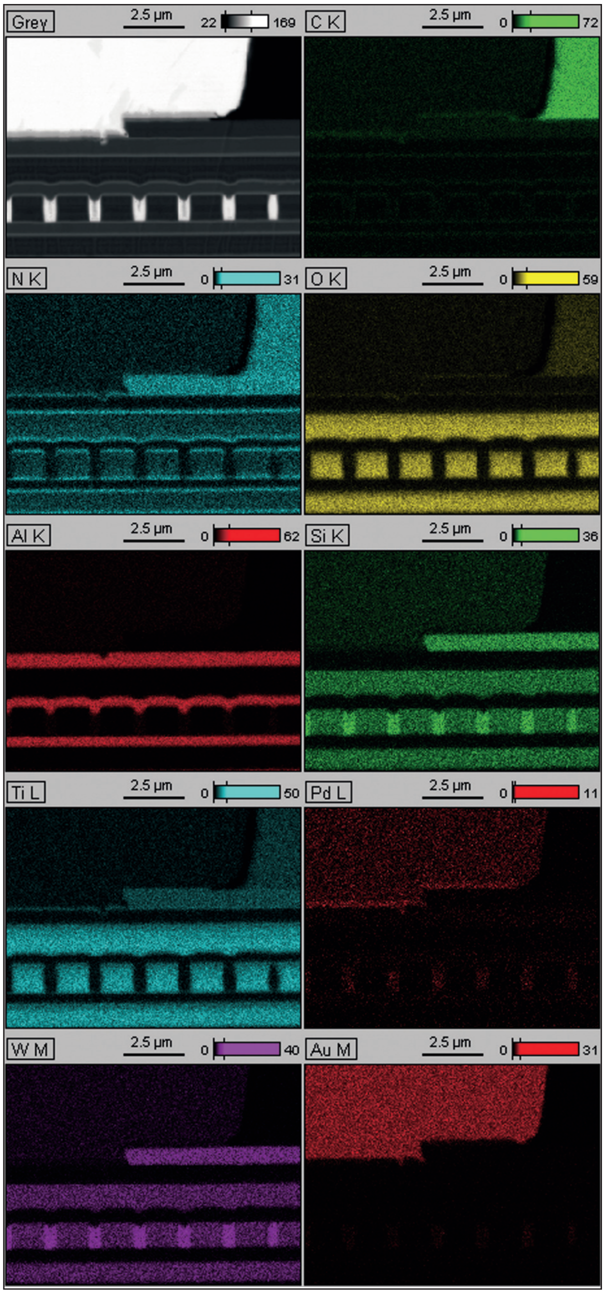


Figure 1: Conventional Peak-Count Maps. Note the similarity of the Si-K and W-M, and the O-K and Ti-L maps.

Quant Mapping

To correct for the peak overlap problems described previously, the quantitative composition routines typically used for analyzing simple spectra have been adapted to process spectral imaging maps. The processing routines in the NORAN System 7 software (1) remove the background in the EDS spectrum, and (2) separate the contributions of each element from overlapped peaks and provide net count maps. If requested by the analyst, a third routine can apply a matrix correction to obtain quantified compositions. All of this analysis in less than a minute.

Quant mapping is a very effective interpretation method because it removes the deleterious effects of overlapping peaks and backgrounds, but it needs a large amount of data to deconvolute the overlapped peaks in each pixel spectrum. Traditionally this means that the acquisition time could be quite long.

The Quant mapping results in Figure 2 were extracted from the same raw data of the previous maps. The elemental maps of Si and W in this view are quite unique in contrast to the similarity of the net-count maps. In addition, the O and Ti maps are also unique. Note that the total acquisition time was just one minute.

Conclusion

It has been a common understanding that the acquisition time necessary for quantitative mapping at high magnification with low accelerating voltage would be quite long, typically longer than 30 minutes, due to at least two reasons. (1) The very small amount of X-ray signals that are available. (2) The huge amount of data needed for adequate peak deconvolution. In this experiment, high quality quantitative mapping results were produced by just one minute of acquisition by using high-performance Shottky FESEM, the UltraDry detector, and the NORAN System 7 analyzer. More quantitative map applications at high magnifications are expected now that the problem of long acquisition time is solved with the use of high-performance FESEM.

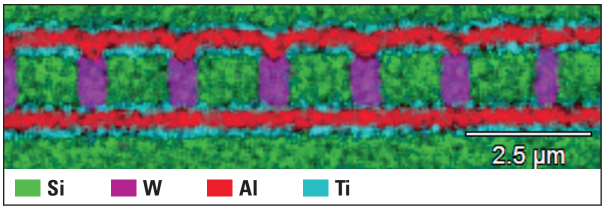


Figure 3: W-Plug Area Magnified. Note how the Si and W regions are clearly separated after just 1 minute of acquisition.

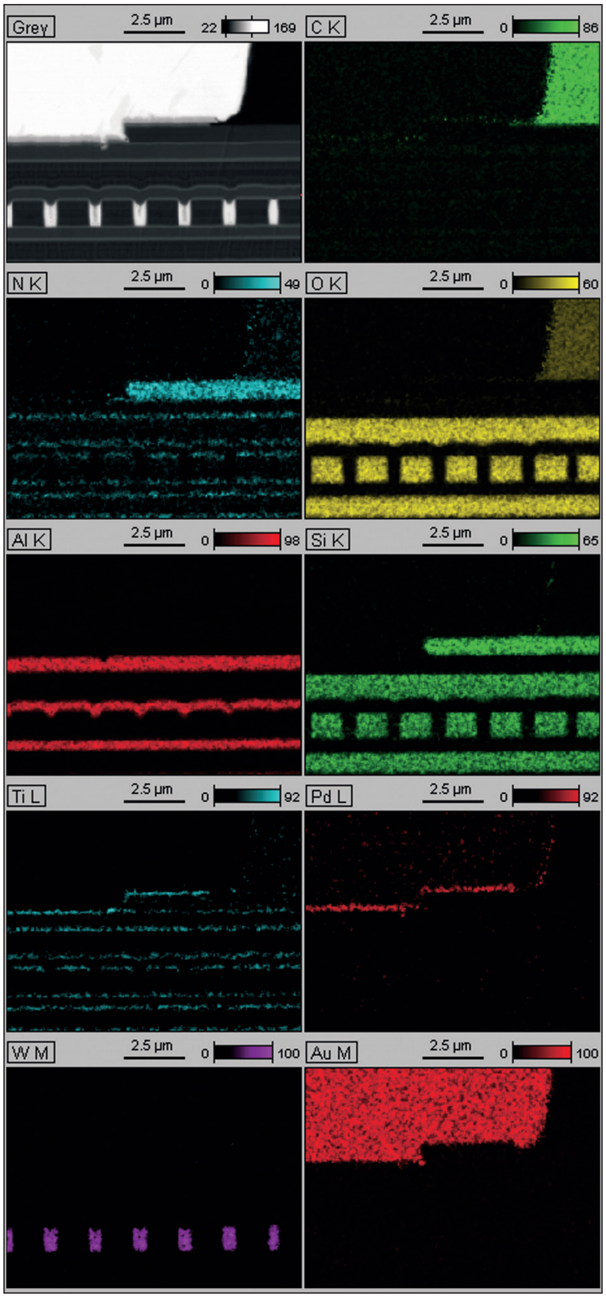


Figure 2: Quantitative Atomic-Percent Element Maps. Note the unique contrast of the O-K and Ti-L, and Si-K and W-M maps.

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