

Paper

Improvement and evaluation of the nano-beam SIMS control system

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Shave-off depth profiling with nano-beam SIMS, our own technique, achieves the highly precise depth profiling with nanometer-scale depth resolution by utilizing a Focused Ion Beam (FIB) micro-machining process to provide the depth profile. This method is to acquire depth profiling by the shave-off scanning mode. However, we could obtain the signals as a function of time because the FIB scanning system and the signal acquisition system were working independently. Therefore, we developed a new system to obtain the signals as a function of two-dimensional position of the FIB. As a result, we could divide a shave-off profile up to 256 along lateral direction. We defined these lateral areas “lanes” and named this new method “multilane shave-off profiling”.

1. Introduction

Recently, electronic components are becoming more miniaturized and are integrated with higher density. In addition, the acquisition of the two- or three-dimensional analysis information is strongly aspired for semiconductor and electronic device industry. Therefore, the establishment of the local analysis in the minute domain is expected. Various analysis methods were used for local domain analysis (SEM: Scanning Electron Microscope, TEM: Transmission Electron Microscope, XPS: X-ray Photoelectron Spectroscopy and EPMA: Electron Probe Microanalysis). Especially, the secondary ion mass spectrometry (SIMS) that had a characteristic of high sensitivity had offered, for example, elemental distribution information for the trouble-shooting analysis. SIMS is one of the most powerful characterization techniques for semiconductor materials and microelectronic devices. Shave-off depth profiling have been developed with nano-beam SIMS, and achieves the highly precise depth profiling with nanometer-scale depth resolution (~0.1 ~ 10 nm) by utilizing a Focused Ion Beam (FIB) micro-machining process to provide the depth profile [1]. Shave-off depth profiling has its own

features: absolute depth scale, pin point depth profiling and application to rough surface and hetero interface. This method is to acquire the depth profile by the shave-off scanning mode (fast horizontal sweeps of an FIB is combined with a very slow vertical sweep). However, the signals could be obtained only as a function of time because the FIB scanning system and the signal acquisition system were working independently. Thus, acquired shave-off profile provided only depth information by integrating the lateral information.

Therefore, we developed a new system to obtain the signals as a function of two-dimensional position of the FIB by synchronizing the FIB scanning and the signal acquisition in one system. Moreover, we originally developed new scanning patterns for different data acquisition modes (interlace scan, micro sweep scan and shave-off scan). As a result, we could divide a shave-off profile up to 256 along lateral direction. We defined these lateral areas “lanes” and named this new method “multilane shave-off profiling”.

The samples (irregular surface, heterogeneous matrix, sphere and elemental distribution) used in the actual industry. Most of

all is depending on shape and composition. In general, "Multilane shave-off" used in order to obtain the information about these materials.

In this paper, we report a new system of nano-beam SIMS and the features of various scanning patterns.

2. Nano-beam SIMS

In the general depth direction analysis, primary ion beam is irradiated the sample surface by the raster scan. However, SIMS has inherent difficulties with quantification because of the called 'matrix effect' and 'geometry effect'. In order to avoid these problems, we developed shave-off scan. In the shave-off process, the primary ion beam is always kept at the edge of the sample and the sample is shaved completely while obtaining the depth profile. Figure 1 shows the schematic image of the shave-off scan.

We have been developing shave-off depth profiling with nano-beam SIMS. Shave-off depth profiling by nano-beam SIMS has its own features: absolute depth scale, pin point depth profiling and application to rough surfaces and hetero interfaces. As for nano-beam SIMS used in our laboratory, the FIB scanning system and the signal acquisition system were working independently. The Scan Generator that controlled the movement of FIB was not controlled by a Personal Computer (PC). A PC only recorded the intensity of the secondary ions that was from mass spectrometer. The intensity of the secondary ion signal could be acquired only as a function of scanning time.

Therefore, we developed a new system to obtain the signals as a function of two-dimensional position of the FIB by synchronizing the FIB scanning and the signal acquisition in one system. Moreover, we originally developed new scanning patterns.

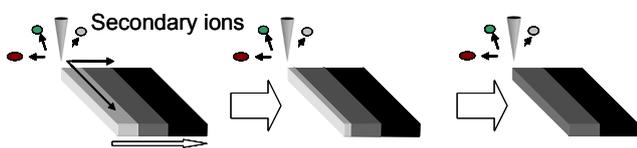


Fig.1. Schematic image of shave-off scanning mode.

3. New system improvement

Figure 2 shows the schematic image of nano-beam SIMS control new system. The digital circuit of Scan Generator, Clock Generator, Signal Counter on a universal board were made

by using general purpose ICs, a clock IC, the resistors and, capacitors. Scan Generator controls the movement of FIB, Clock Generator determines scanning speed and the 121-channel parallel Signal Counter accumulates a section of secondary ion mass spectrum. Specially designed counter controller manages the action of the signal counter including reset, accumulation and data transfer. A parallel I/O is used to command the action of the digital system. However, high speed data transfer is difficult. Therefore, we use DMA transfer to perform spectrum data transfer.

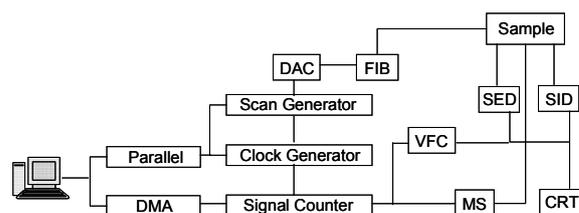


Fig. 2. Schematic image of nano-beam SIMS control new system.

4. Various scanning patterns

We newly developed various scanning patterns for different data acquisition modes. Each data acquisition mode has following features. Figure 4, 5, and 6 show the schematic image of scanning modes, Interlace scan, Micro sweep scan and Shave-off scan, respectively.

Image observation mode (Interlace scan)

About 10 fields per second. No data acquisition. Use for the primary ion beam adjustment, secondary ion beam adjustment and search for analysis part.

Image shooting mode (Micro sweep scan)

Several 10~ 100 seconds per field. 16-bit data structure per pixel. Necessary resolution is 256×256 pixels. Micro sweep scan is most adequate to perform effective data transfer.

Mapping mode (Micro sweep scan)

Acquiring an image of 256×256 pixels ×121-channel spectrum. The scan is Micro sweep scan. Because large number of data must be transferred in short time, the DMA transfer is utilized.

Shave-off scan mode (Multilane shave-off)

Tens of thousands of the raster scan..

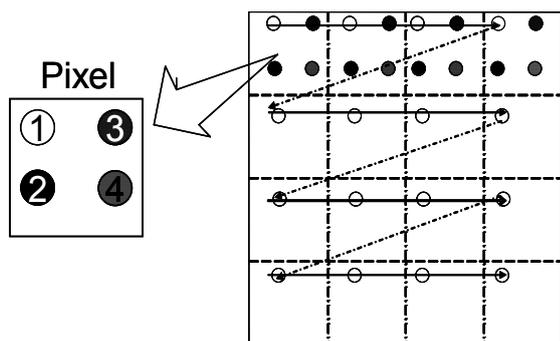


Fig. 3 Schematic image of Interlace scan.

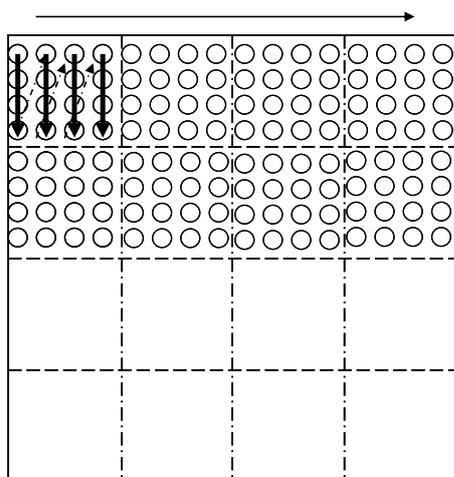


Fig.4 Schematic image of Micro sweep scan.

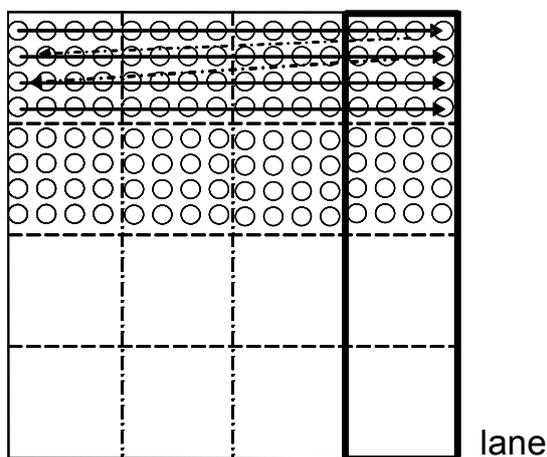


Fig.5 Schematic image of shave-off scan.

When we first adjust the primary ion beam optics or find the region to analyze, a real time image of the sample should be displayed on a CRT screen. Therefore, refresh rate of at least 10

fields per second is required. The image resolution of 256 dots or 64K pixel is practically sufficient. Important point is that the sample surface should be irradiated by the ion beam uniformly. Distance between adjacent beam irradiation spots should be less than the typical diameter of FIB, 50 nm. This is common to all scan modes (Interlace scan, Micro sweep scan and Shave-off scan). This results in 40 MHz D/A conversion for FIB scan. This is practically impossible conversion rate. In order to avoid this problem, we developed the Interlace scan. FIB hits different point in a pixel at each field scan. After several seconds, FIB hits all of 4096×4096 points. Data transfer is not performed. Because there is few sample damage, it is used to search for analysis part.

In the Micro sweep scan for image shooting and mapping mode, FIB successively hits all points in a pixel. Data transfer is required only at the end of each pixel. Because large number of data must be transferred in short time, the DMA transfer is utilized.

In the Multilane shave-off for shave-off scan mode, FIB scans on very high density. To perform the data transfer in several tens of micro seconds, the DMA transfer is utilized. By synchronizing the FIB scanning and signal acquisition in one system, shave-off profile can be divided into 1-256 lateral parts which correspond to “lanes” and named this new method “multilane shave-off profiling”

5. Conclusion

We improved new control system for nano-beam SIMS. The FIB scanning and the signal acquisition were synchronized in one system. Moreover, various scanning patterns were developed. These results enabled us to choice the most appropriate scanning pattern for each data acquisition mode.

6. References

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