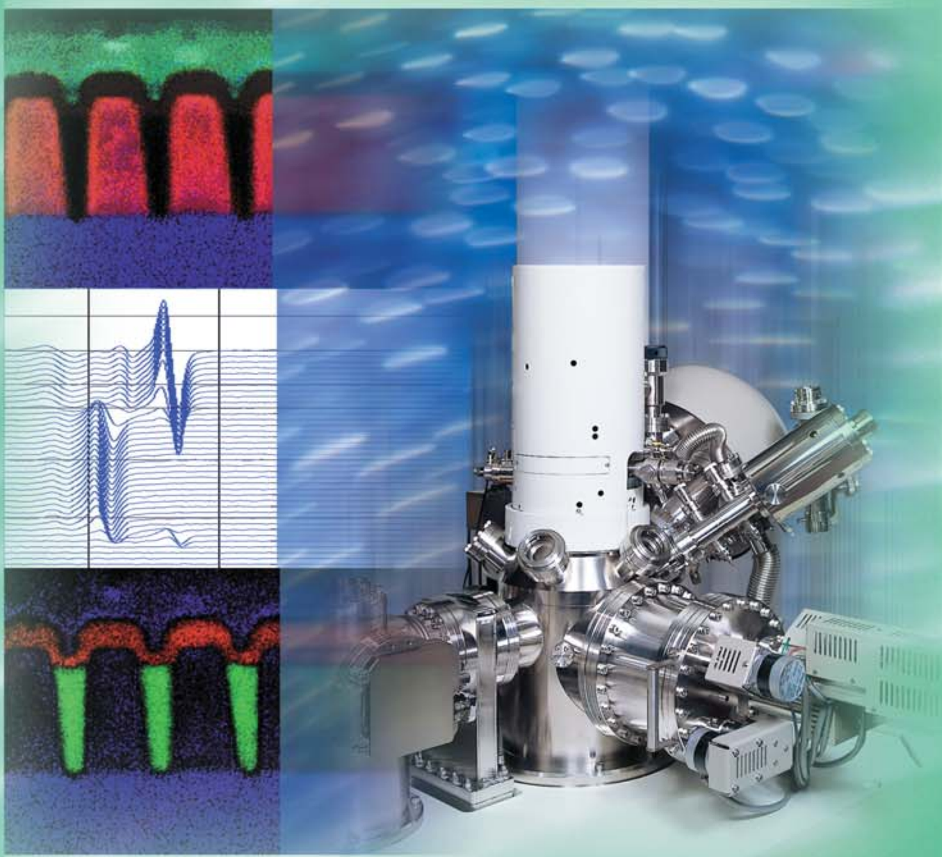
FE-AUGER

JAMP-9500F

Field Emission Auger Microprobe



JEOL

Serving Advanced Technology

JAMP-9500F

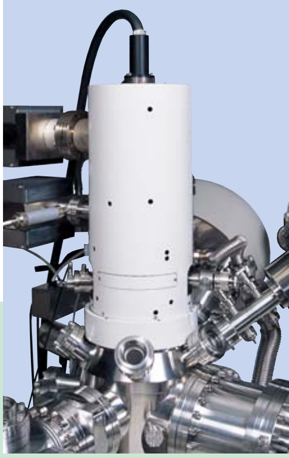
Field Emission Auger Microprobe

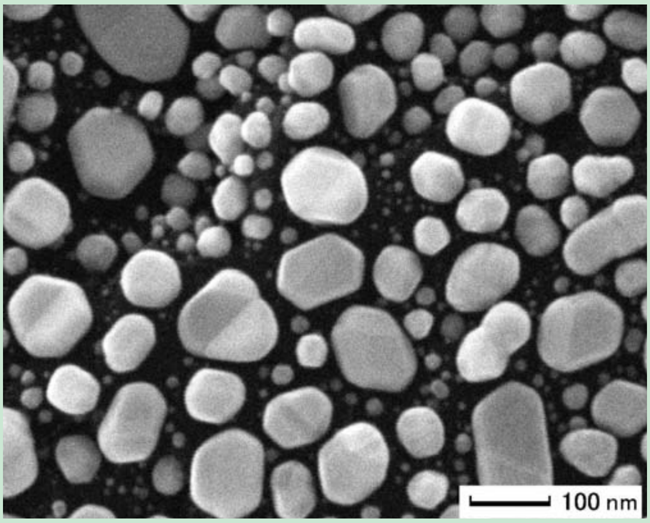
JEOL has introduced the JAMP-9500F Field Emission Auger Microprobe, featuring the world's highest spatial resolution. JEOL's newly developed electron optical system has greatly improved spatial resolution, making it possible for the JAMP-9500F to achieve the minimum probe diameter of 3 nm (for resolution of secondary electron image (SEI)) and 8 nm (for Auger analysis).
In addition, the JAMP-9500F uses a hemispherical electrostatic energy analyzer (HSA) with a multi-channel detector, which has been optimized for Auger analysis. This HSA offers high energy resolution analysis with high sensitivity, demonstrating its full effectiveness in chemical state analysis.
The JAMP-9500F allows surface image observation using high resolution SEI, Auger image analysis and line profile analysis. What's more, this instrument can perform depth profile analysis while employing ion etching. Moreover, a new neutralizing ion gun makes Auger analysis of insulating materials possible. The specimen stage allows a large sample (up to 95 mm in diameter) to be analyzed. The JAMP-9500F can analyze any specimens while making a nanometer area analysis capability (several 10 nm in diameter) possible.

Main Features

- 3 nm SEI resolution by highest performance electron optical system
- 8 nm probe diameter for Auger analysis
- Energy resolution can be varied from 0.05% to 0.6%.
- Chemical state analysis in several 10 nm areas
- New neutralizing ion gun allows Auger analysis of insulating materials.
- Large specimen stage enables a large sample (up to 95 mm in diameter) to be analyzed.

Electron Optical System for Nanometer Area Analysis





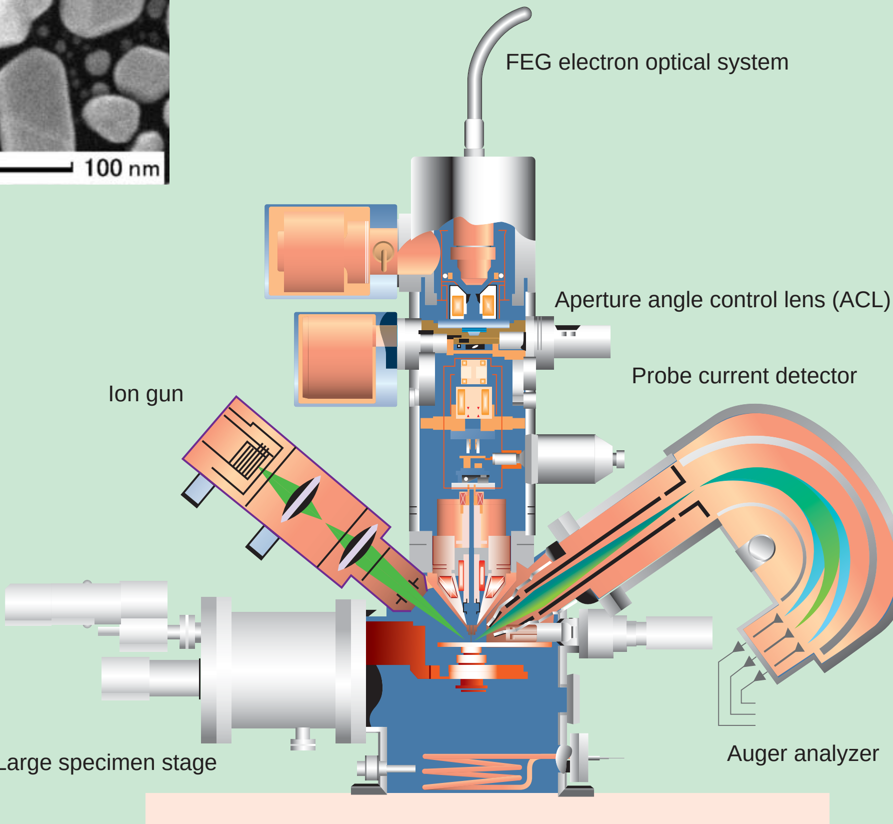
High resolution SEI

The left figure shows Au particles evaporated on graphite. It confirms that the image resolution (dark space resolution) is 3nm.

FEG electron optical system

In order to perform micro area Auger analysis, an electron illumination system is required to produce both a low current probe for high spatial resolution observation and a high current probe for Auger analysis. For this purpose, the JAMP-9500F employs a Schottky-type field emission electron gun (FEG). This FEG combined with a low aberration objective lens achieves minimum probe diameter: 3 nm for SEI and 8 nm for Auger analysis.

In addition, in the FEG, a low aberration condenser lens has been integrated with the anode of the FEG (In-lens FEG). This design enables the electron optical system to efficiently collect electrons emitted from the FEG, producing large probe currents more than 200 nA.



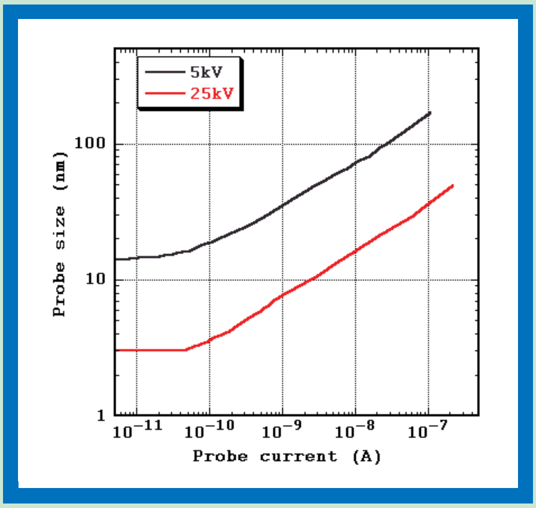
Schematic diagram of Field Emission Auger Microprobe

Automatic aperture angle control lens

The JAMP-9500F uses a new automatic aperture angle control lens (ACL). The ACL automatically optimizes the aperture angle of the objective lens, which determines the diameter of the incident probe to the specimen, for a wide range of probe current from the small current mode at high spatial resolution to the large current mode during Auger analysis. With the help of the ACL, it is always possible to observe images with highest resolution.

Relation of probe current and probe diameter

The right figure shows the relation of probe current and probe diameter at 25 kV and 5 kV accelerating voltages. The high performance electron optical system produces a small diameter probe even at a large current. The 8 nm probe diameter can be obtained under the high resolution Auger analysis condition (25 kV, 1 nA). It is possible to obtain a nanometer area analysis at large currents.



Relation of probe current and probe diameter

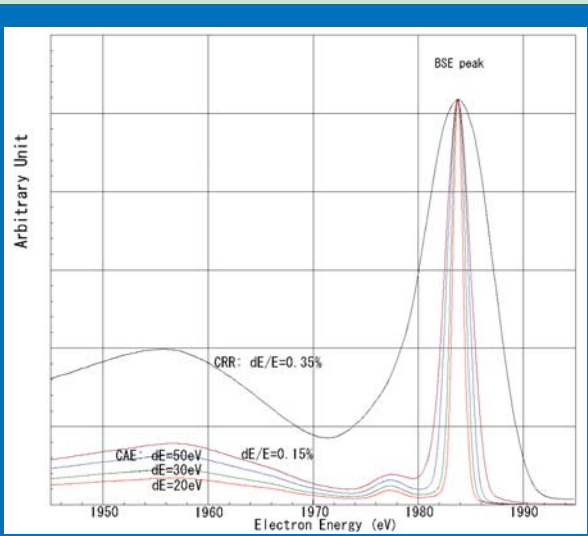
Probe current detector

The pneumatic driven Faraday cup integrated in the electron optical system, accurately measures the beam current without requiring specimen movement. This detector is useful for the measurement of probe current in the analysis of large specimens and insulating materials.

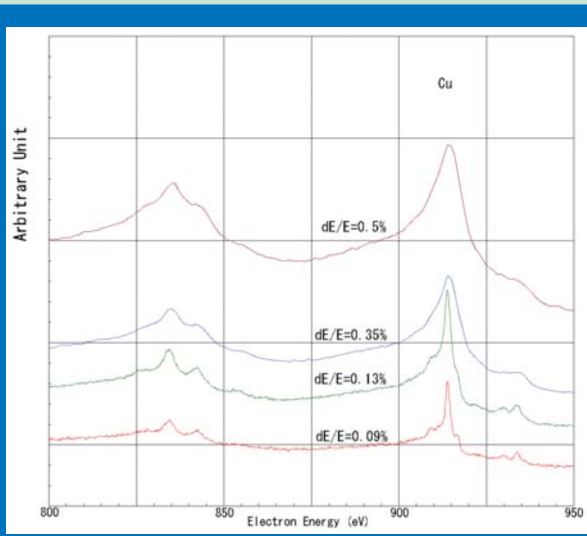
High Performance Auger Analysis

Auger analyzer with high energy resolution

JAMP-9500F uses a hemispherical electrostatic energy analyzer (HSA) as the Auger electron detector. The HSA, combined with a large acceptance angle input lens and a multi-channel detector, can obtain high sensitivity comparable or superior to the conventional cylindrical mirror analyzer (CMA). The energy resolution of HSA is variable from 0.05% to 0.6%. This feature enables the best Auger analysis by selecting energy resolution for analytical purposes, chemical state analysis at high resolution (0.15%) or elemental analysis at routine resolution (0.35%: equivalent to CMA). Still more, two analysis modes are provided: constant retarding ratio(CRR) mode and constant analyzer energy(CAE) mode. CRR mode is used for Auger electron spectroscopy (AES) and CAE mode for energy loss spectroscopy (ELS) and X-ray photoelectron spectroscopy (XPS).



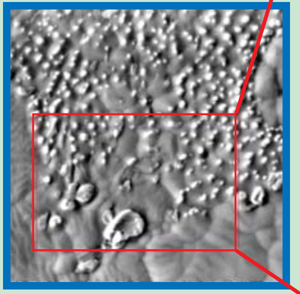
Spectra of backscattered electrons obtained at various energy resolutions.



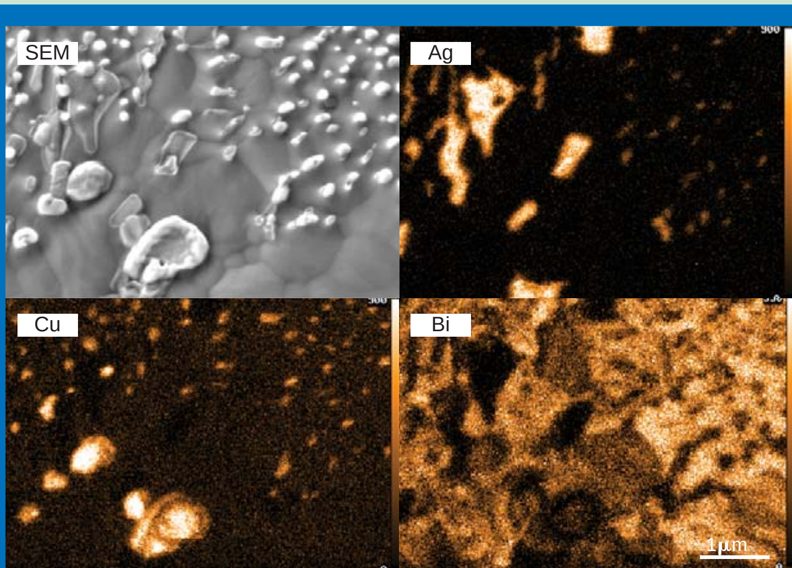
Auger spectra of Cu obtained at various energy resolutions.

Auger image analysis

By acquiring Auger images and line profiles, using the high performance HSA, it is possible to observe element distributions and chemical state information. As a new function for Auger image observation, a selected area observation function has been incorporated. This function allows to specify acquiring areas of Auger images on an SEI ; therefore, it is possible to perform high speed measurement of Auger images for interested area. The figures show the SEI for the surface of a lead free solder and Auger images of Cu, Ag and Bi obtained from the specified analysis area in the SEI.



SEI of lead free solder and specified analysis area (within red box).



Auger image measurement of precipitates (Ag, Cu and Bi) on lead free solder.

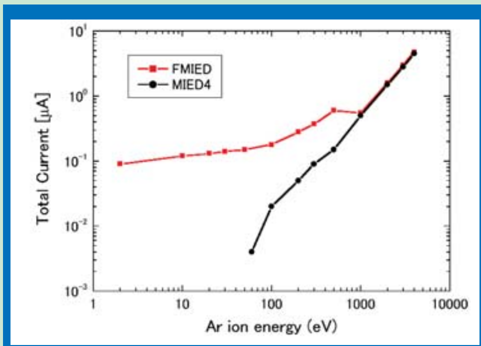
Large specimen stage

Auger Microprobes are used in the analysis of metals and semiconductors, as powerful, surface analysis instruments for micro areas. The conventional instrument analyzes a large specimen such as hard disk after cutting it. The JAMP-9500F uses a new specimen stage designed to accommodate a large sample up to 95 mm in diameter, without cutting it. This stage can be installed in the JAMP-9500F with the large analyzing chamber and specimen exchange chamber. The large specimen stage thus allows Auger analysis of hard disks as they are.

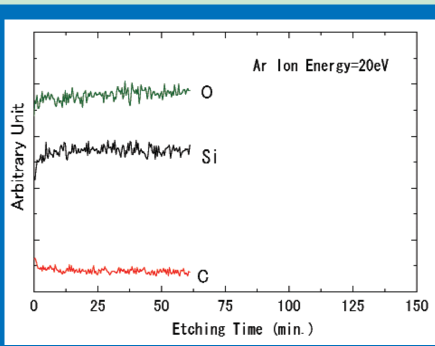
A Variety of Analytical Modes

Ion gun with neutralization function

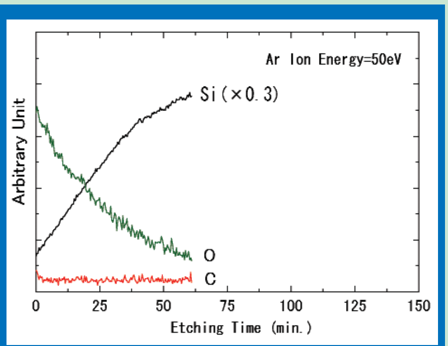
We developed an ion gun (FMIED: floating type micro ion etching device) that neutralizes the electric charges on the specimen surface by irradiating low energy Ar ions on the specimen. The following experimental data show the neutralizing effect of the new ion gun. The left figure shows a comparison data between FMIED and a conventional ion gun (MIED4:micro ion etching gun) as function of ion current and ion accelerating voltage and the FMIED can obtain high ion current densities at low accelerating voltages (10 to 30 eV) (left figure). In the center and right figures, we show the change of surface element intensities, when a native oxide film (less than 2 nm thick) on a Si substrate is irradiated with the ion beam at the accelerating voltages of 20 eV and 50 eV. For 20 eV Ar ion irradiation, the native oxidized layer is not sputtered and no change of surface element intensities was seen, while with 50 eV ion irradiation, the SiO_2 film is sputtered. This result demonstrates that low energy ion irradiation is effective for the neutralization of electric charges on surfaces, without sputtering. This ion gun, having both the etching mode and the neutralization mode, enables Auger depth analysis of insulating materials.



Ion current characteristics versus accelerating voltage of ion gun.



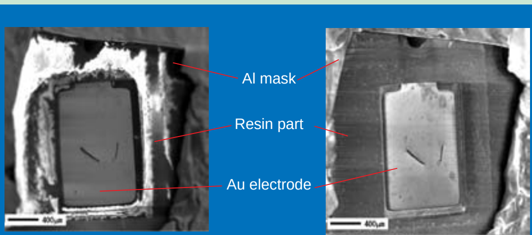
Sample: Native oxide film on Si (less than 2 nm)
Change of surface elements when irradiated by Ar ions with 20 eV accelerating voltage.



Sample: Native oxide film on Si (less than 2 nm)
Change of surface elements when irradiated by Ar ions with 50 eV accelerating voltage.

Auger analysis of insulating materials

Low energy ions were irradiated on a printed circuit board constructed of Au electrode surrounded by an insulating material. The figures are secondary electron images (SEI) and Auger spectra of the Au electrode, obtained before and after Ar ion irradiation. In SEI observation, the abnormal contrast (left image), due to the charging on the resin part, disappeared after ion irradiation, resulting in normal contrast (right image). In the Auger spectra, the normal spectra (right figure) were acquired with low energy ion irradiation.

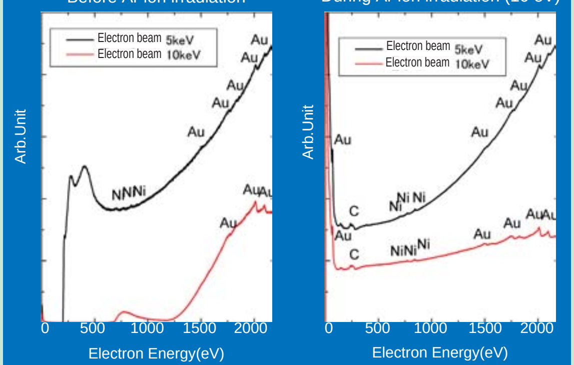


Before Ar ion irradiation   After Ar ion irradiation

Probe conditions
Magnification: ×50, Tilt angle: 45°

Change in SEIs of Au electrode before and after Ar ion irradiation

Before Ar ion irradiation   During Ar ion irradiation (10 eV)



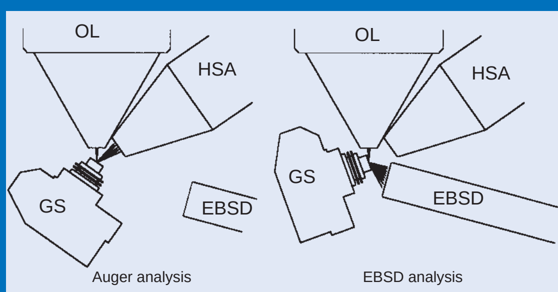
Change in Auger spectra of Au electrode before and during Ar ion irradiation

Expandable software for Auger depth profiling

Auger depth profiling obtains the elemental distribution as a function of depth, by alternately acquiring spectrum and ion sputtering. The main application of depth profiling is used for multi layers samples. During depth profiling, the depth profile and all spectral data (differential and integral) are displayed simultaneously. In addition, the software incoporates "modify mode" that the current acquisition is paused, adjusted to add additional elements or analysis points and also to delete unnecessary elements and analysis points. 20 elements for 10 different analysis points can be analyzed at one depth profiling work.

UHV-SEM capability

SEI imaging under ultra high vacuum (UHV) allows the more surface sensitive observation than that under the conventional vacuum. In particular, by cleaning the specimen in UHV, it is possible to observe images of contamination free surfaces. In addition, the combined system of an electron backscattered diffraction(EBSD) allows observation of electron channeling patterns without contamination. This method is especially useful for EBSD analysis of highly reactive elements such as Mg and rare earth elements.



Layout of EBSD detector and specimen stage (GS) for EBSD analysis

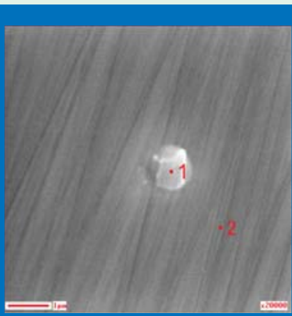
Micro Area Analysis : From Element Analysis to Structure Analysis

Analysis of micro particles and defects on hard disk

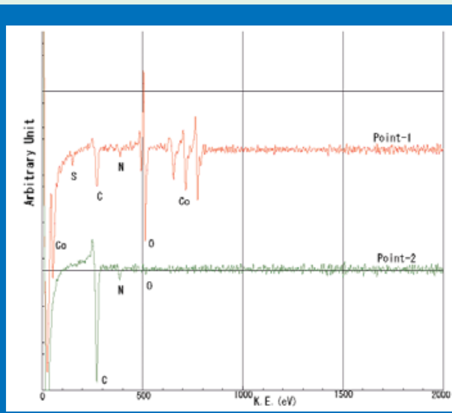
When micro particles enter in the hard disk production process or the surface of a hard disk in use, these particles result in defects of the disk and crashing a disk. The following data shows examples of Auger analysis of these particles and defects on the surface of the hard disk.

Analysis of micro particles on hard disk

Recording devices such as hard disks have a multi-layer structure of magnetic materials and protection film on an Al substrate. The micro particles, which enter in the production process of these devices, bring the shorter lifetime of the devices. The figures show the SEI of a micro particle on the hard disk and the Auger spectra obtained from the particle and protection film. At this particle, Co was detected. This particle has the same element as the magnetic material contained in the hard disk and measured about 0.8 μm in size. By Auger analysis of micro particles, the causes of defects can be found out.



SEI of particle on hard disk.
1 and 2 indicate analysis points.
Accelerating voltage: 10 kV

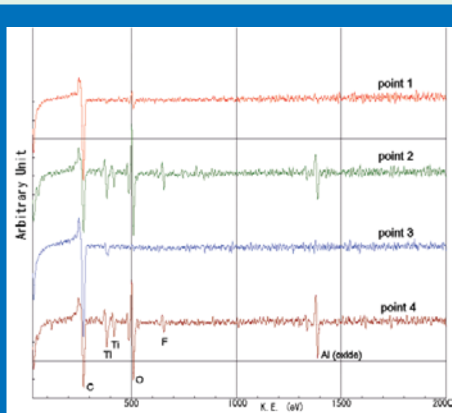


Auger spectra obtained from particle (point-1) and matrix (point-2).

Defect analysis of hard disk

The figures show the SEI of a defect and the Auger spectra obtained from the analysis points specified in the SEI. At point-2 and -4, Ti, F and Al were detected, indicating that the depth of the scratches in the defect reached the Al substrate. At point-1, the center of the defect causing the scratches, only carbon was detected, the same element as the normal part (point-3), so the micro particle is surmised to be a material, its main element being carbon.

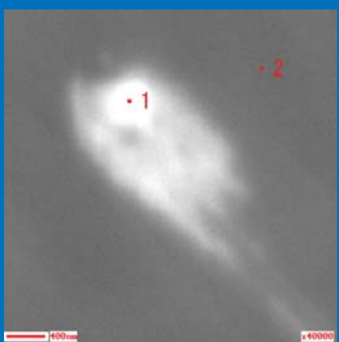
SEI of defect. 1~4 indicate analysis points.
Accelerating voltage: 10 kV
Probe current: 10 nA



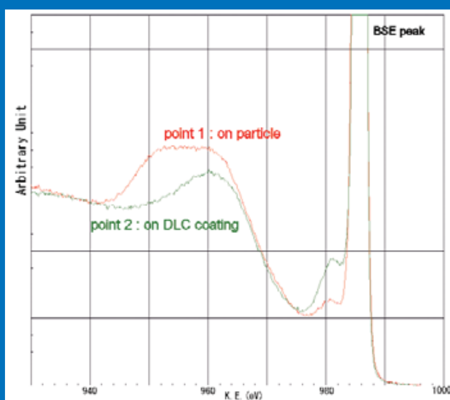
Auger spectra obtained from various locations of defect and normal part.

Structure analysis using energy loss spectroscopy (ELS)

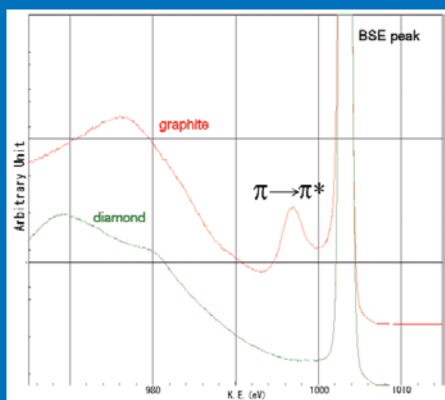
SEI shows the same particle as the above analysis at 1 keV accelerating voltage and 1nA current. Furthermore, the right figure shows the standard energy loss spectra obtained from graphite (HOPG) and diamond. In the spectrum obtained from graphite, an energy loss spectrum of π-electron excitation, which is characteristic of graphite, is observed. In the spectrum of diamond, the shape of the background is a trapezoid that is peculiar to diamond. The energy loss spectrum from the micro particle has a mixed shape of the diamond and diamond like carbon (DLC) of the top film on the disk. Since it is considered that the DLC has adhered to the micro particle during sliding over the hard disk, the micro particle at the center of the defect is found to be diamond.



SEI of defect.
Accelerating voltage: 1 kV
Probe current: 1 nA



Energy loss spectra obtained from defect and surface of hard disk.
Red: on the particle (point-1)
Green: DLC film (point-2)



Standard energy loss spectra obtained from graphite (HOPG) and diamond.
Red: graphite (HOPG)
Green: diamond

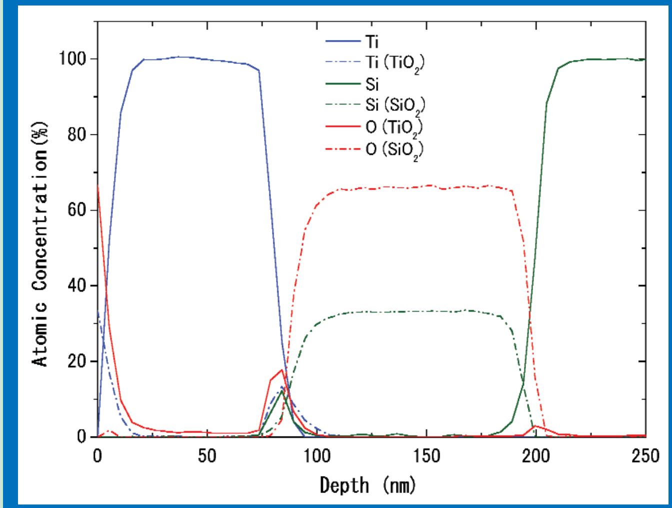
Auger Chemical State Analysis

Depth profile analysis with high energy resolution mode

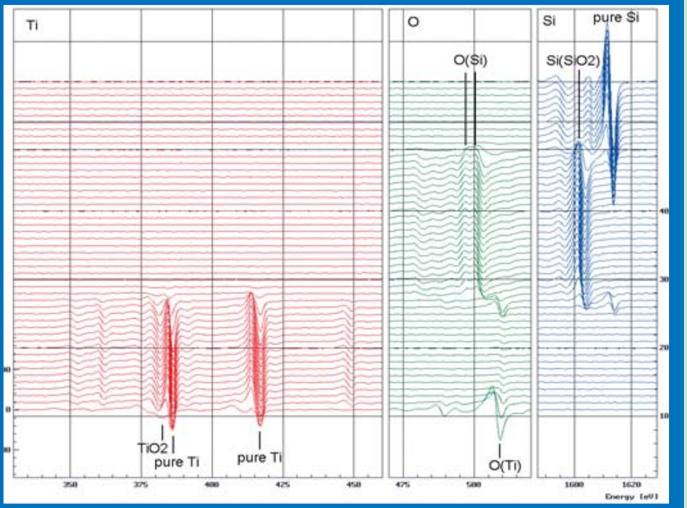
The chemical shift and fine structure of Auger spectra can be observed with the high energy resolution analyzer(HSA). The figures show the depth profile of Ti(60nm)/SiO_2(100nm)/Si and its spectra in depth. In the right figure, Si peak of SiO_2 is discriminated clearly from the elemental Si peak at approximately 10eV shift . The oxigen peak combined with Ti is also detected at 5eV energy shift from the oxigen peak combined Si. As for Ti spectra, broad peak constructed of fine structure, these peaks usually change its shape depending on the chemical condition.

In the depth profiling, both the pure Si peaks and O peaks of TiO_2 are detected in the Ti/SiO_2 interface. This result means clearly that Ti has been oxidized and Si has been reduced at the Ti/SiO_2 interface.

The curve fitting calculation for these spectra, even if broad Ti peaks, enables to obtain depth profiles of each chemical state respectively Ti and TiO_2 or Si and SiO_2 by using the high energy resolution mode.



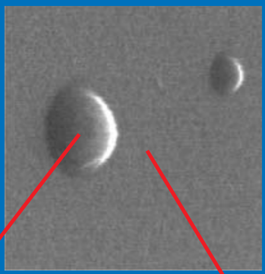
Depth profile obtained after curve fitting for spectra of Ti(60 nm)/SiO_2 (100 nm)/Si.

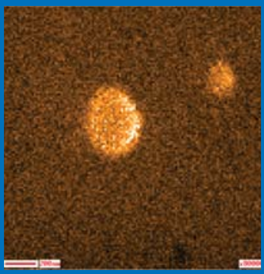


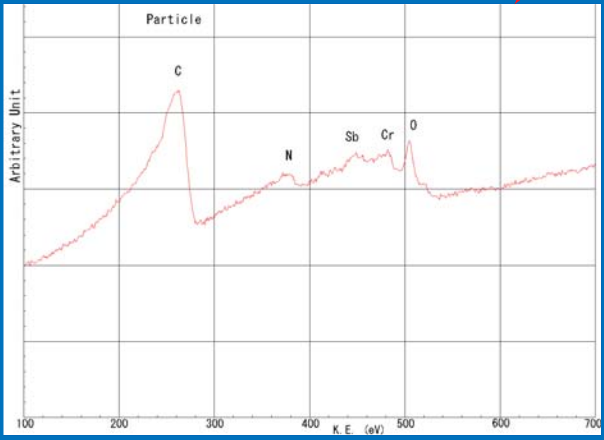
All spectra, obtained during depth profiling and shown in the depth direction .

Analysis of micro particles on color filter

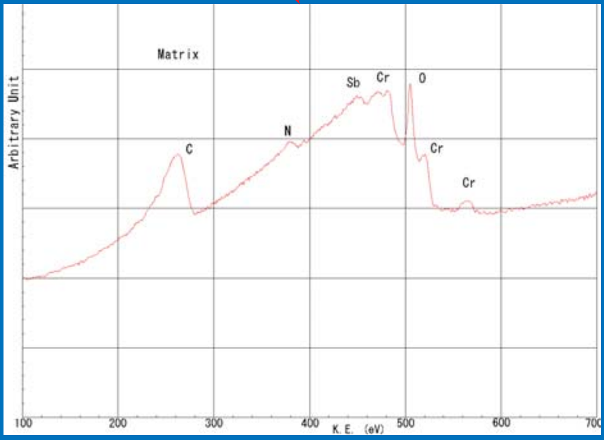
The figures show the analytical result of micro particles adhering to a Cr film on the substrate of a color filter. In the SEI, the particles about 0.1 to 0.4 µm in size are observed. Auger analysis of the particles and the substrate (matrix) indicate that the main element of the particles is carbon. Contrast in the SEI disappeared when the electron beam continued to irradiate the particles, so this particle is considered to be an organic material. The C-KLL Auger image also shows that the particle's main constituent is carbon.


SEI of particle on color filter
(Accelerating voltage: 10 kV)


C-KLL Auger image



Auger spectrum obtained from micro particle.



Auger spectrum obtained from substrate (matrix).

Main Specifications

Electron illumination system	
Electron gun	Schottky field emission gun
Accelerating voltage	0.5 to 30 kV
Lens system	2 stage condenser lens, aperture angle control lens (ACL), objective lens
Probe current detector	Faraday cup (pneumatic driven), specimen current measurable
Probe current	10^{-12} to 2×10^{-7} A
SEI resolution	3 nm (at 25 kV, 10 pA)
Probe diameter for Auger analysis	8 nm (at 25 kV, 1 nA)
Magnification	×20 to 500,000
Auger analysis system	
Analyzer	Hemispherical electrostatic energy analyzer (HSA)
Input lens	Acceleration type 2 stage electrostatic lens system
Detection system	Multi-channel detection
Energy range	0 to 2,500 eV
Analysis mode	CRR (constant retarding ratio) mode, CAE (constant analyzer energy) mode
Energy resolution ($\Delta E/E$)	0.05 to 0.6%
Sensitivity	840,000 cps/7 ch or more (at 10 kV, 10 nA Cu-LMN, 0.6% resolution, 60°tilt)
Large specimen stage	
Specimen movement	Y: ±10 mm, X: -48 mm to +10 mm, Z: ±6 mm, T (tilt): 0 to 90°, R (rotation): 360°(endless)
Stage drive	Motor drive (X, Y, Z, T, R)
Stage control	Possible through host computer or using joystick
Specimen holder	for 3.5 inch disk, 2.5 inch disk, 20 mm in diameter (8 mm thick), 12 mm in diameter (4 mm thick)
Ion gun	
Ionization method	electron bombardment type with superimposed magnetic field
Ion extraction method	Floating method
Ion energy	0.01 to 4 keV
Preset memory function	Possible to record 256 conditions
Ion current (absorbed current)	2 μA or more at 3,000 eV, 0.03 μA or more at 10 eV
Differential pumping characteristics	1: 10,000 or more
Neutralization function	Built-in
UHV evacuation system	
Ultimate pressure in specimen chamber	5×10^{-8} Pa or less
Specimen exchange time	Within 5 minutes
Computer system	
Host computer	Workstation
Software	
Data acquisition	Spectrum, depth profile, line profile, Auger image, SEI (secondary electron image)
Data processing	Numerical processing, depth raw data processing, qualitative analysis, quantitative analysis, mage processing, data display, utility

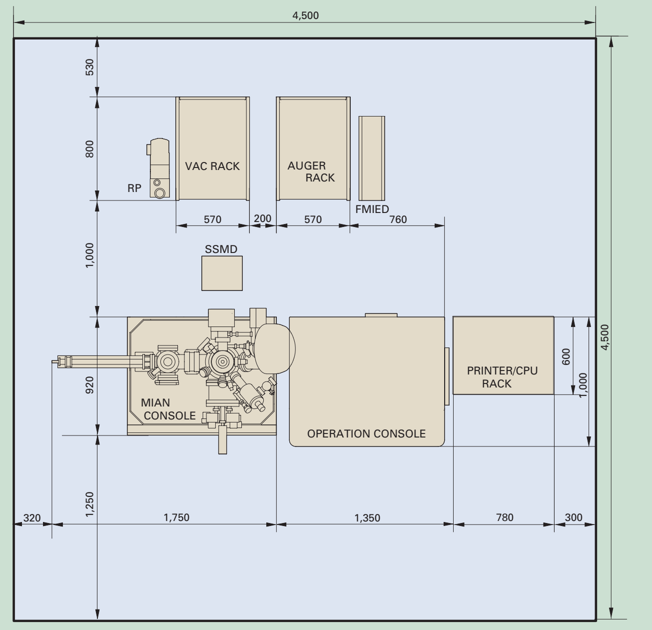
Main Optional Attachments

Backscattered electron detector
UHV-EDS
UHV-EBSD
Cross sectional image analysis software
Stage scan image analysis software
Scheduling analysis software
Curve fitting software

Installation Requirements

Power	Single phase, 200 V AC, 50/60 Hz, 6 kVA Single phase, 100 V AC, 50/60 Hz, 3 kVA Allowable fluctuation: within ±10%
Grounding terminal	100 Ω or less (×1)
Cooling water	
Instrument side faucet	R 3/8 (external thread) (×1)
Flow rate	1.8 to 2.2 L/min
Pressure	0.08 to 0.25 MPa (gauge pressure)
Temperature	20±0.1°C
Instrument side drain	R 3/8 (external thread) (×1)
Compressed air (used for pneumatic valves and air suspension mounts)	
Pressure	0.5 to 1.0 MPa (gauge pressure)
Instrument side inlet	Nylon tube (6 mm O. D.×4.5 mm I. D.)
Dry nitrogen gas (used for vacuum venting)	
Purity	99.98% or better
Pressure	0.4 to 0.5 MPa (gauge pressure)
Instrument side pipe terminal	Taper pipe thread, PT 1/4-inch, external thread
High purity Ar gas (used for ion gun)	
Purity	99.999% or better
Pressure	0.4 to 0.5 MPa (gauge pressure)
Instrument side pipe terminal	Taper pipe thread, PT 1/4-inch, external thread
Installation room environment	
Room size	
Floor area	4,500 mm × 4,500 mm or more
Entrance	1,200 mm wide × 2,000 mm high or more
Temperature	20±5°C
Humidity	60% or less
Stray magnetic fields	
AC field	0.3 μT (3 mG) (p-p) or less
Irregular fluctuation	0.1 μT (1 mG) (p-p) or less
Floor vibration	3 μm or less (at 4 Hz or higher) 0.5 μm or less (at 4 Hz or higher)
Acoustic noise	60 dB or less (F mode)

Installation Layout



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