Surface Analysis

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OUTLINE

Introduction
Scanning Electron Microscopy (SEM)
Transmission Electron Microscopy (TEM)
Atomic Force Microscopy (AFM)
Energy Dispersive Analysis of x-rays (EDAX)
Auger Electron Spectroscopy
X-ray Fluorescence Spectroscopy (XPS)
Secondary Ion Mass Spectroscopy (SIMS)
Capacitance Voltage Measurements
Surface Charge Analyzer
INTRODUCTION

Surface analysis refers to a collection of techniques to get information about the chemical or physical nature of a surface. (few µm)
LEO EVO 50
SCANNING ELECTRON MICROSCOPE (SEM)

Primary Electron Beam

Auger Electrons 10Å

Secondary Electrons, 20Å

Back scattered Electrons

Characteristic X-rays

1 μm

Sintillator (Phosphor Coated)

Photo multiplier Tube (low work Function)

X-Ray Continuum

Specimen Current Detector

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TRANSMISSION ELECTRON MICROSCOPE

Primary Electron Beam

Specimen Support Grid

Very Thin Specimen < 1 µm

Sintillator (Phosphor Coated)

hv

-3000 V

-1000 V

-4000 V

-2000 V

Photo multiplier Tube (low work Function)

Vout

R

+200 V
SEM EXAMPLES
SEM EXAMPLES
SEM WITH FOCUSED ION BEAM (FIB)
SEM WITH FOCUSED ION BEAM (FIB)

FIB allows crosssection SEM images to be made at any point by cutting a trench with a focused beam of argon ions.
AFM – ATOMIC FORCE MICROSCOPE
Piezoelectric Motors Scan Tip in X and Y, Electronics control Z such that the Tunneling Current $I$ is Constant. The Control Voltage for $Z$ is a Measure of Surface Topology.
ATOMIC FORCE MICROSCOPE (AFM)
**Surface Analysis**

**K-TEK Nanotechnology**

![K-TEK Nanotechnology](image)

**CSG10**

$345.00 - $6,325.00

Golden Silicon AFM Probes for Nonconductive Contact Mode

<table>
<thead>
<tr>
<th>Name</th>
<th>Range</th>
<th>Discount</th>
</tr>
</thead>
<tbody>
<tr>
<td>20% off 3 packs of 15 probes</td>
<td>3 - 1000</td>
<td>20%</td>
</tr>
</tbody>
</table>

Quantity: 15

$345.00

2 in stock (can be backordered)

Categories: 20% off 3 packs of 15 probes, AFM Probes, Golden

Tags: Adhesion Force Imaging (Spectroscopy), Atomic Force Acoustic Microscopy (AFAM), Contact, General Topography, Lateral Force Microscopy (LFM), Life Sciences, Liquid Scanning, Mechanical Properties/Force Curves, Nanoindentation and Lithography, Non-Contact/Tapping, Phase Imaging Mode, Spectroscopy

SKU: CSG10/15
K-TEK TYPES OF AFM PROBES

Modes and Applications
- Adhesion Force Imaging (Spectroscopy)
- Atomic Force Acoustic Microscopy (AFAM)
- Conductive AFM (CAFAM)
- Contact
- Critical Dimension (CDAFM)
- Electrical
- Electrostatic Force Microscopy (EFM)
- Force Modulation
- General Topography
- Hardened/Enhanced Wear Resistance
- High Aspect Ratio
- High Resolution Imaging
- Kelvin Probe Microscopy
- Lateral Force Microscopy (LFM)
- Life Sciences
- Liquid Scanning
- Magnetic Force Microscopy (MFM)
- Mechanical Properties/Force Curves
- Nancindentation and Lithography
- Non-Contact/Tapping
- Phase Imaging Mode
- Piezoresponse/Piezoforce Microscopy (PFM)

Series
- Scanning Capacitance Mode (SCM)
- Scanning Electrochemical Potential Microscopy (SECPM)
- Scanning Near-field Optical Microscopy (SNOM)
- Scanning Spreading Resistance Mode (SSRM)
- Scanning Thermal Microscopy (SThM)
- Scanning Tunneling Microscopy (STM)
- Spectroscopy
- Surface Potential Microscopy (SPoM)
- Torsional Resonance (TR)
- Trenches/Holes
- Carbon Nanotube
- Colloidal
- Diamond
- Etalon
- Golden
- Needleprobes
- Optical Micro Tips
- Top Visual
ATOMIC FORCE MICROSCOPE (AFM)

- **Standard**
  - Sharp Apex
  - Slender
  - Long
  - Used in Contact mode

- **CD Mode (Conical and Flared)**
  - Flared tip able to measure undercut sidewalls
  - Used in non-contact mode
ENERGY DISPERSIVE ANALYSIS OF XRAYS (EDAX)

- Primary Electron Beam
- Auger Electrons 10Å
- Secondary Electrons, 20Å
- Back scattered Electrons
- Characteristic X-rays
- X-Ray Continuum

1 µm
ENERGY DISPERSIVE ANALYSIS OF XRAYS (EDAX)

IRON

Atomic Number 26

En = \(-13.6 \frac{Z^2}{n^2}\)

E1 = \(-9194\) eV
E2 = \(-2298\) eV
E3 = \(-1022\) eV

E = hν or \(λ = \frac{hc}{E}\)

x-ray

Notation: K x-rays are associated with transitions to 1st shell, L x-rays to the 2nd shell. α x-rays are between adjacent shells, B x-rays are two shells apart, etc.
EDAX

Crystal Detector

Cryogenic Semiconductor Detector

Liquid Nitrogen Cooled Semiconductor Detector
EDAX

Phoenix microanalyzer including EDAX III acquisition electronics and PC.
EDAX

Spectrum of silicon oxynitride acquired at 5 kV.
EDAX ANALYSIS OF FAILED RF PIN

Failed RF Pin: 40X

Failed RF Pin: 320X

Point A & B Analyzed using EDAX
MLK MODE SELECT ELEMENT
LK Z=30 ZN
PR=S 319 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H

COUNTS

POINT B

20.48KEV

ENERGY KEV

MLK MODE SELECT ELEMENT
ML Z=80 HG
PR=S 150 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H

COUNTS

POINT A

20.48KEV

ENERGY KEV

MLK MODE SELECT ELEMENT
LK Z=29 CU
PR=S 319 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H

COUNTS

POINT B

20.48KEV

ENERGY KEV

MLK MODE SELECT ELEMENT
MLK Z=41 NB
PR=S 150 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H

COUNTS

POINT A

20.48KEV

ENERGY KEV
AUGER ELECTRON SPECTROSCOPY

Auger Electrons 10Å
Primary Electron Beam
Secondary Electrons, 20Å
Back scattered Electrons
Characteristic X-rays
X-Ray Continuum

1 µm
AUGER
Auger analysis showed an aluminum particle contaminated the wafer.
AUGER

- Simultaneous Process
- Ionization of Core Electron
- Upper level electron falls into lower energy state
- Energy release from second electron allows Auger electron to escape
- The illustrated LMM Auger electron energy is ~423 eV
  \( \text{EAuger} = \text{EL}_2 - \text{EM}_4 - \text{EM}_3 \)

http://www.cea.com/cai/augtheo/process.htm
- Chart of principal Auger electron energies
- Dots indicate electron energies for principal Auger peaks for each element

http://www.cea.com/cai/augtheo/energies.htm
**ESCA or XPS**

Electron Spectroscopy for Chemical Analysis (ESCA) or X-ray Photo Electron Spectroscopy (XPS)
SECONDARY ION MASS SPECTROSCOPY (SIMS)

Ion Beam Gun

Sample

Mass Spectrometer
The Quadrupole Filter has voltages such that down the center there is a zero potential equipotential surface. Only ions of a certain mass make it all the way to the photomultiplier tube. The voltage applied to the filter at radio frequency and DC selects the mass.
RGA
CAPACITANCE VOLTAGE MEASUREMENTS

Apply a DC voltage (V) to the capacitor and measure the capacitance. High frequency and low frequency capacitance measurement techniques are available.

\[ C_{ox} = \varepsilon_0 \varepsilon_r \frac{\text{Area}}{X_{ox}} \]

-10 < V < +10
CV MEASUREMENTS

N-Type Silicon
- High Frequency: Accumulation
- Low Frequency: Depletion
- Inversion: \( V_{FB} \)
- \( C_{min} \) to \( C_{FB} \)

P-Type Silicon
- High Frequency: Depletion
- Low Frequency: Accumulation
- Inversion: \( V_{FB} \)
- \( C_{min} \) to \( C_{FB} \)
**SCA**

- Signal Amplifier
- High Voltage Amplifier
- Light Controller and Modulator
- Data Acquisition
- Computer

Diagram:
- Capacitive Pickup
- Guard Electrode
- LED Light Source
- Oxide
- Silicon

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Login: FACTORY
Password: OPER

<F1> Operate

<F1> Test   Place the blank spot in middle of wafer on center of the stage
Select (use arrow keys, space bar, page up, etc)
  PROGRAM = FAC-P or FAC-N
  LOT ID = F990909
  WAFER NO. = D1
  TOX = 463 (from nanospec)

<F12> start test and wait for measurement
<Print Screen> print results
<F8> exit and log off
<ESC> can be used anytime, but wait for current test to be completed
EXAMPLE OF SCA OUTPUT MEASURED AT RIT
EXAMPLE OF SCA OUTPUT MEASURED AT RIT

[Graph showing doping concentration on a wafer with color-coded regions indicating different concentration levels.]

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REFERENCES


3. EDAX Inc., 91 McKee Drive, Mahwah, NJ 07430-9978, Tel (201) 529-3156

1. Calculate the wavelength of the $K_\alpha$ and $L_B$ x-ray for copper.
2. Explain how SIMS gives doping profiles.
3. Why can’t Auger and a ESCA give doping profiles.