Surface Analysis

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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
Surface analysis refers to a collection of techniques to get information about the chemical or physical nature of a surface. (few µm)
Surface Analysis

LEO EVO 50

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AMRAY 1830 1 & 2
Surface Analysis

SCANNING ELECTRON MICROSCOPE (SEM)

- Primary Electron Beam
- Secondary Electrons, 20Å
- Auger Electrons, 10Å
- Sintillator (Phosphor Coated)
- Specimen Current Detector

- 1 µm
- Back scattered Electrons
- Characteristic X-rays
- X-Ray Continuum

- Photo multiplier
- Tube (low work Function)

- +200 V
- -1000 V
- -2000 V
- -3000 V
- -4000 V

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TRANSMISSION ELECTRON MICROSCOPE

Primary Electron Beam

Specimen Support Grid

Specimen < 1 µm

Sintillator (Phosphor Coated)

+200 V

-3000 V

-1000 V

-4000 V

-2000 V

Photo multiplier Tube (low work Function)

R

Vout

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LEO EVO 50 SEM & EDAX
SEM EXAMPLES
SEM WITH FOCUSED ION BEAM (FIB)
FIB allows cross-section SEM images to be made at any point by cutting a trench with a focused beam of argon ions.
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)
**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
Surface Analysis

ENERGY DISPERSIVE ANALYSIS OF X-RAYS (EDAX)

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

1 µm
ENERGY DISPERSIVE ANALYSIS OF X-RAYS (EDAX)

**Iron**

Atomic Number 26

En = -13.6 \( Z^2/n^2 \)

E1 = -9194 eV

E2 = -2298 eV

E3 = -1022 eV

\[ E = h \nu \quad \text{or} \quad \lambda = \frac{h}{E} \]

x-ray

Notation: K x-rays are associated with transitions to 1st shell, L x-rays to the 2nd shell. \( \alpha \) x-rays are between adjacent shells, B x-rays are two shells apart, etc.
Crystal Detector

Cryogenic Semiconductor Detector

Liquid Nitrogen Cooled Semiconductor Detector
EDAX

Phoenix microanalyzer including EDAX III acquisition electronics and PC.

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Spectrum of silicon oxynitride acquired at 5 kV.
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

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

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

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

AUGER ELECTRON SPECTROSCOPY

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

1 µm

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AUGER
Auger analysis showed an aluminum particle contaminated the wafer.
Surface Analysis

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 (E_{Auger} = E_{L2} - E_{M4} - E_{M3})

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.ce.a.com/cai/augtheo/energies.htm
ESCA or XPS

Electron Spectroscopy for Chemical Analysis (ESCA) or X-ray Photo Electron Spectroscopy (XPS)
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
Apply a DC voltage (V) to the capacitor and measure the capacitance. High frequency and low frequency capacitance measurement techniques are available.
CV MEASUREMENTS

N-Type Silicon

- Low Frequency
- Depletion
- Inversion
- High Frequency

P-Type Silicon

- Low Frequency
- Inversion
- Accumulation
- High Frequency

$V_T$, $V_{FB}$, $C_{min}$, $C_{FB}$
Surface Analysis

SCA

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

Capacitive Pickup
Guard Electrode

LED Light Source

Silicon
Oxide

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Surface Analysis

SCA

P-type Wafer

Qind

Inversion

Wd

WT

Wmid gap

Accumulation

WFB

N-type Wafer

Accumulation

Wd

WT

Wmid gap

Inversion

WFB

Qind
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

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EXAMPLE OF SCA OUTPUT MEASURED AT RIT
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.