SECONDARY ION EMISSION

- Sputtering produces neutral species, positive and negative ions
- Ions have angular divergence and distribution in kinetic energy
Primary Ions

- Inert Gas (Ar, Xe, etc)
  Minimize chemical modification of surface

- Oxygen
  Enhance positive ion production

- Cesium
  Enhance negative ion production

- Liquid Metal (Ga)
  Small spot for enhanced lateral resolution
Figure 1

Interference-Free Detection Limits
The ion optical system

1 Cesium ion source
2 Duoplasmatron ion source
3 Primary beam mass filter
4 Immersion lens
5 Specimen
6 Dynamic transfer system
7 Transfer optical system
8 Entrance slit
9 Electrostatic sector
10 Energy slit
11 Spectrometer lens
12 Spectrometer
13 Electromagnet
14 Exit slit
15 Projection lenses
16 Projection display and detection system
17 Deflector
18 Channel-plate
19 Fluorescent screen
20 Deflector
21 Remote controlled Faraday cup
22 Electron multiplier
POLYMER-COATED A1

STATIC: POSITIVE, NO NEUTRALIZATION

SECONDARY ION COUNTS

MASS (amu)

10^1 10^2 10^3 10^4

CH₃  CH₂  CH  C

H₂O  NA

POLYMER-COATED A1

NON-STATIC: POSITIVE, NEUTRALIZED

SECONDARY ION COUNTS

MASS (amu)

10^1 10^2 10^3 10^4

A1  B  C  D  E  F  G

dynamic

static
Typical Dynamic SIMS Survey

POS. SIMS SURVEY 12/28/90 T=6.25 KDL. SPUT. ANGLE=70.0
FILE: n=10 No Standard Bulk O+
TOTAL TIME PER STEP= 0.1500 SEC.

LOG (COUNTS)

M.O. C. O Na K Ca Fe Al V Cr Ti Mo Co Ni Cu H C 0

M.O.

LOG (COUNTS)

100 110 120 130 140 150 160 170 180 190 200

100

M.O.

Complex molecule

File: n=10 No Standard Bulk O+
TOTAL TIME PER STEP= 0.1500 SEC.
Adhesive Bond Details
2024 Aluminium Alloy
abraded + silane coupling agent
bonded with FM-73 epoxy adhesive

Fig. 5.22. SIMS composition map of an adhesive bond fracture on 2024 aluminium treated with
silane, showing the locus of fracture based on the distribution of Si and Al. The dark grey areas in
the map contain no Al or Si and so correspond to adhesive at the surface. The white areas contain
both Al and Si so correspond to the surface fracturing at the silane-oxide interface.
Different ionization mechanisms → different energy dependences

- charge exchange
- core ionization + Auger decay
  requires close, "hard" collision
- autoionization

Fig. 4.48. Energy dependence of the secondary ion intensity of various ions emitted from Ar⁺ ion bombarded Si (Wittmaack, 1977).
Correlation: Auger emission kinetic SIMS

Fig. 3.13 Primary ion energy dependences of the $\text{Si}^{2+}$ and $\text{Si(LMN)}$ atomic Auger yields for the four projectile $\text{Ne}^+$, $\text{Ar}^+$, $\text{Kr}^+$, $\text{Xe}^+$ [3-163]
Fig. 3.14 Energy distributions of secondary ions emitted during the sputtering of Al, Mg, and Si by 10 keV Ar$^+$ at 35° [3-157]
Oxygen effects can be HUGE

Fig. 4.50. Steady state intensity of various secondary ions emitted from 4 keV Ar⁺ bombardment of B-doped Si as a function of the O partial pressure in the chamber (Maul, 1974).
Fig. 5.14. Ion yields of silicon secondary ions for clean Si, oxygen-saturated silicon or silicon dioxide surfaces.

Fig. 5.13. Secondary ion yields for the indicated elements with (filled circles) or without (open circles) oxygen.

Suggest use of primary O ion beams to increase sensitivity.
HUGE variations of ionization probability along periodic table

Fig. 19: Relative positive ion yield $S^+$ for different elements obtained under $O^-$ bombardment by different authors. Copyright 1972 by the American Association for the Advancement of Science.
Fig. 5.15. (a) Positive ion yields for the indicated targets bombarded with 13.5 keV O\(^{-}\) at normal incidence. (b) Negative ion yields for the indicated targets bombarded with 16.5 keV Cs\(^{+}\) at normal incidence.

O enhances positive ion yields

Cs enhances negative ion yields
Large enhancements lead to large problems with background gas.

Figure 4.11 SIMS measurements of hydrogen depth profiles for 5 keV Cs sputtering of a silicon sample implanted at 35 keV with a dose of $1 \times 10^{14}$ H ions/cm$^2$. The effect of the H$_2$O partial pressure in the analysis chamber upon the H dynamic range is evident. [From Magee and Botnick, 1981.]
Effects of using O beams

- **B Transient vs. Beam Energy**
  - RT/CH1
  - 1E19
  - 1E18
  - 1E17
  - Depth (microns)
  - 2.0 keV
  - 5.5 keV
  - 8.8 keV
  - 10.5 keV
  - 13.8 keV

  *B⁺ ion yield transients for various O⁺ primary ion energies.*

- **4 KeV B implant in Si**
  - RT/CH3
  - 1E21

  - Corrected Profile
  - Original Profile
  - Correction Function

  *Plot of the original B⁺ depth profile of a 4 keV B implant, the ion yield correction function, and the resulting B⁺ depth profile after correcting for the ion yield transient. O⁺ primary ion beam: 5.5 keV impact energy, ~45° from normal.*
Fig. 4.49. Normalised energy distributions of various ions sputtered from Al using 10 keV Ar$^+$ ions (Wittmaack, 1975).

Fig. 5.17. Biassing the secondary ion optics to only accept high energy secondaries excludes molecular ions which interfere with and limit the dynamic range of dopant profiling. The lower curve was obtained by offsetting the secondary ion optics by 40 V to eliminate a molecular ion.
Fig. 13. Low damage SIMS analysis of (a) oxygen uptake on molybdenum and (b) sputter removal of an oxidized surface layer [11]. To account roughly for differences in experimental conditions, the original numbers [11] for (b) have been divided by two.
Fig. 4.55. Ion yield intensities on SIMS observed during oxidation (full lines) and sputter removal (dashed lines) of O on Mo (fig. 4.54) plotted as a function of the MoO⁺ yield intensity (Wittmaack, 1977).

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Fig. 4.56. O⁺ and O⁻ yields from Ne⁺ bombardment of W[100] with various coverages of O. The abscissa are given as the O⁺ yield at a fixed Ne⁺ ion energy of 2 keV (a) and 0.5 keV (b) relative to the maximum such yield (after Yu, 1978).