Nanometer-Scale Trace Analysis

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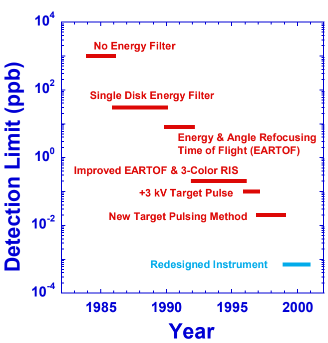
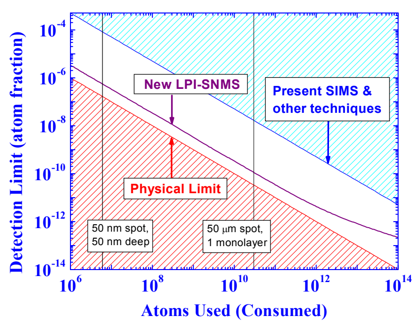
Motivation/Major Accomplishments

- Trade off between sample size and achievable detection limit
  - For sputtering or laser desorption
  - Quantified by useful yield (atoms detected/atoms consumed)
- Laser post-ionization secondary neutral mass spectrometry (LPI-SNMS)
  - Useful yields significantly higher than competing techniques (e.g., SIMS)
  - Well suited for trace analysis of small samples.
- New reflectron time-of-flight (TOF) mass spectrometer
  - Especially designed to optimize useful yield
  - One of three instruments completed
  - Extraction from a large volume ($4 \times 4 \times 3$ mm^3)
  - Transmitted >98% efficient.
  - Large ionization volume contains >40% of desorbed species
  - Calculated useful yield >30%
- Permits nanometer-scale analysis at trace levels
  - For detection limited is controlled by sample size
  - For rare or precious sample where sample consumption is important

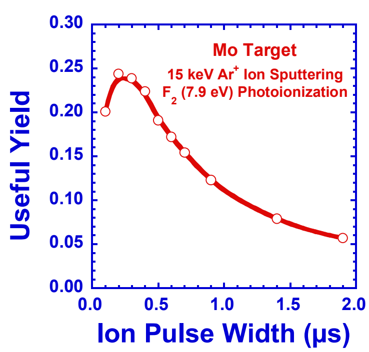
Ultra-Trace Analysis and Detection Limit





Measured Useful Yield = 24%

- Useful yield measured as function of primary ion pulse width.
- 1 in 4 atoms detected.
- Result X100 better than best SIMS
- Ion optics simulations predict 1 in 3 ions detected.
- Instrument improvements possible to reach calculated useful yield.



Small Sample Analysis

Monolayer	Nanometer-Scale	Bulk
100 nm square	50 nm cube	(300 µm)^2 × 0.1 µm
1.5×10^5 atoms	6×10^6 atoms	4×10^{14} atoms
1 atom = 7 ppm	1 atom = 160 ppb	400 atoms = 1 ppt

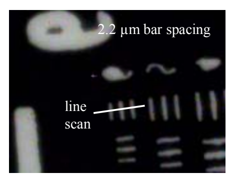
All three examples demonstrate the same problem:

- Finite sample size. So few atoms, every atom counts.
- Characterization must be accomplished before consuming the total number of atoms available.

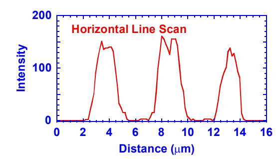
Sub-µm Analyses Accomplished by Ion Sputtering or Laser Desorption

The new instrument incorporates

- a liquid metal ion source with 50 nm spot size for nanometer-scale analysis
- an in situ, high numeric aperture microscope
  - for imaging of sample surfaces
  - for laser desorption of samples for analysis.



Microscope image



Measured line scan shows 0.5 µm resolution.

Impact and Future Directions

- Analysis of small samples at trace levels never before achievable (ppt)
- Most sensitive in the world for surface analysis
- Many new analytical applications now possible
- Future applications
  - Characterization of nanometer-scale surface features with monolayer depth resolution
  - Quantitative analysis of extremely rare isotopes
  - Detections of solar wind elements from the collectors of NASA's Genesis Discovery Mission (available in 2005)
  - Compositional analysis of 100 nm interstellar dust particles from NASA's Stardust Mission (available in 2006)

A New Time-of-Flight Instrument for Quantitative Surface Analysis, I. V. Veryovkin, W. F. Calaway, J. F. Moore, M. J. Pellin, and D. S. Burnett, NIM B (submitted, July 2003).

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