TN 104

EAGLABS℠ Time-Of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) Services

Technique Note

October 13, 2008 (Version 1.0)

TOF-SIMS provides full elemental and molecular analysis with excellent sensitivity

Introduction

Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS), also known as static SIMS, is a technique that is widely used to characterize surfaces and surface contaminants. It is closely related to dynamic SIMS, which uses a constant beam of primary ions to etch a sputter crater into a sample over a period of minutes. In contrast, TOF-SIMS uses a pulsed ion beam and does not significantly sputter etch or damage the sample surface on the timescale of the analysis. This lack of damage makes it an ideal technique for the analysis of surfaces for the presence of both elemental (most elements in the periodic table) and molecular species, with a very shallow sampling depth (1-2nm). In combination with a time of flight mass spectrometer, the technique provides excellent survey capabilities with sensitivity in the part per million (ppm) range. The primary ion beam used in TOF-SIMS instruments (typically ^{69}Ga or ^{197}Au) can be focused to sub-µm dimensions, meaning the technique can be used to analyze features in the 1µm to 500µm range. Both conducting and insulating samples can be analyzed successfully.

Principles

TOF-SIMS works by rastering a pulsed beam of focused primary ions across the sample of interest, resulting in the emission of secondary ions which are characteristic of the materials present in the top several monolayers of the sample. By accurately measuring the masses of the detected ions they can be identified and related to the chemical species present on the sample surface. The data obtained can be in the form of mass spectra, or ion images of specific species. Depth profiles can also be obtained if the technique is done in conjunction with ion sputtering (with either the same primary ion gun or using an additional Cs or O ion beam).

Common Applications

Its excellent surface sensitivity, ability to analyze organic materials and other insulators, excellent detection limits, and ability to provide elemental and molecular information makes TOF-SIMS an ideal technique for addressing the following types of applications.

- Surface characterization of organic and elemental materials
- Mapping the lateral distribution of surface species
- Contaminant identification (down to the ppm range)
  - Elemental
  - Molecular
- Quantitative analysis of surface metals on wafers
- Failure analysis
  - Adhesion
  - Bond Pads
  - Coatings
- Evaluation of cleaning processes (QA/QC)
- Identification of stains, discolorations, and hazes
- Examining surfaces before and after processing to identify differences
- Comparison of samples processed or stored in different environments to determine surface changes

Strengths

- Surface sensitive; top few monolayers
- Detection limits in the ppm range
- Survey analysis
- Elemental and molecular information
- Can analyze insulators and conductors
- Sub-µm spatial resolution possible in imaging mode
- Can analyze up to 200mm wafers intact

Limitations

- Absolute quantitation is difficult without extensive calibration
- Can be too surface sensitive so careful sample handling/packaging is important
- Samples must be vacuum compatible
- Datasets can be complex

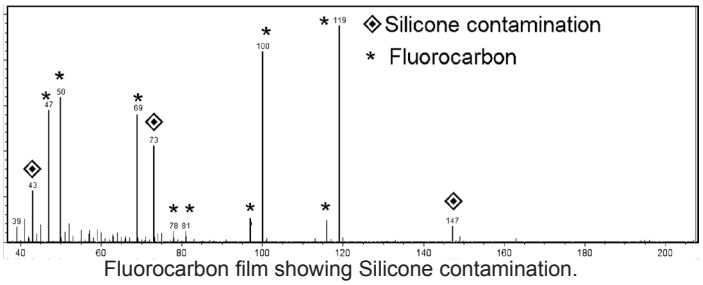
Technique Comparisons

Other surface analysis tools with similar depths of analysis or applications include X-ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES) and Fourier Transform Infrared Spectroscopy (FTIR). XPS provides quantitative concentrations and chemical bonding information that is not normally obtained directly using TOF-SIMS. AES can provide better spatial resolution images for elemental species, but with poorer sensitivity. FTIR can provide complementary organic information and has a greater information depth and access to commercial library spectra. This may make FTIR a better choice for identification of macroscopic amounts of material, where extreme surface information may not be of prime interest.

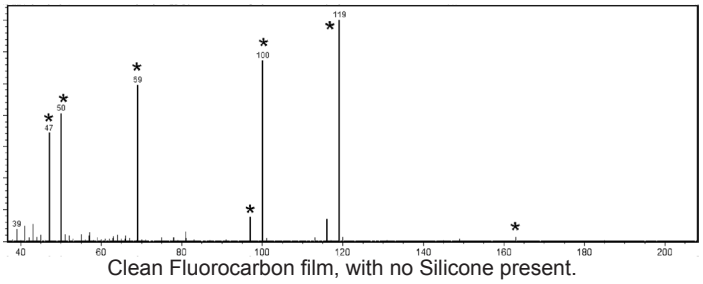
TOF-SIMS at Evans Analytical Group

EAG has 5 TOF-SIMS instruments located throughout the world. Some of these instruments contain special capabilities such as large sample stages for disks or wafers up to 200mm in size or sample cooling for the analysis of semi-volatile materials in vacuum. Our TOF-SIMS experience is unsurpassed with many of our TOF-SIMS scientists having more than 10 years of practical TOF-SIMS experience across a range of industries and applications. Historically, the California lab of EAG (Charles Evans & Associates) was directly involved in the early commercialization of TOF-SIMS instruments giving EAG unmatched practical analytical experience.

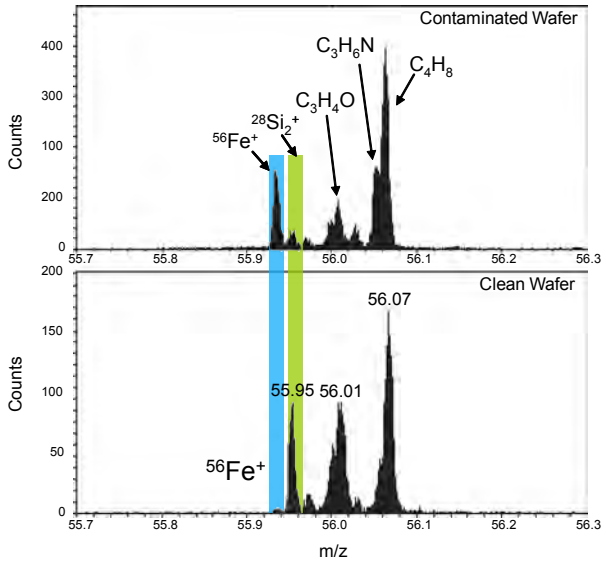
Typical Data



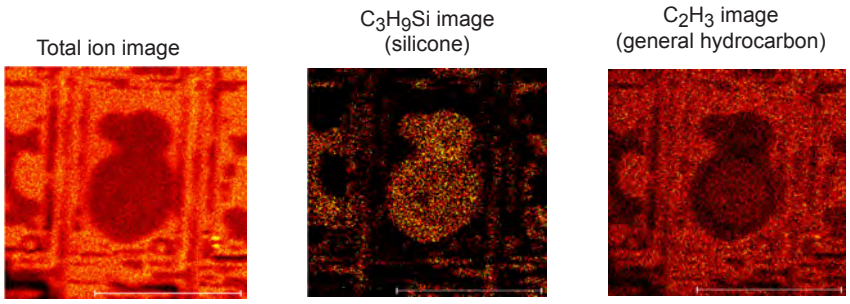
Fluorocarbon film showing Silicone contamination.



Clean Fluorocarbon film, with no Silicone present.



High mass resolution spectra of iron (Fe) on a contaminated Si wafer compared to a clean wafer.



TOF-SIMS ion images of residue on a flat panel display (150µm field of view)