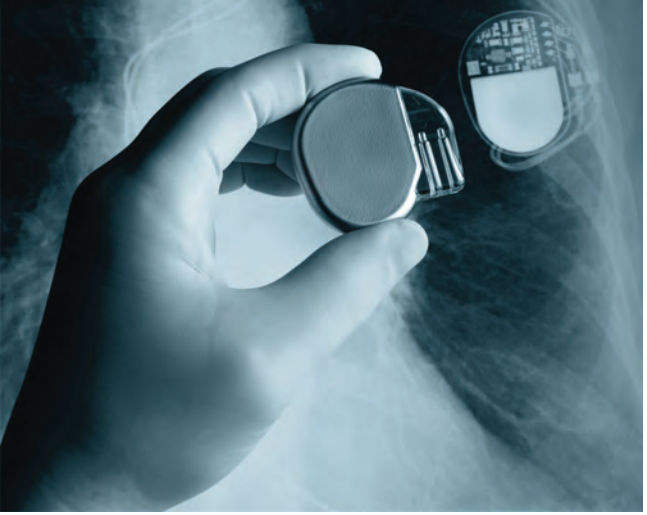
PHYSICAL ELECTRONICS
A DIVISION OF ULVAC-PHI

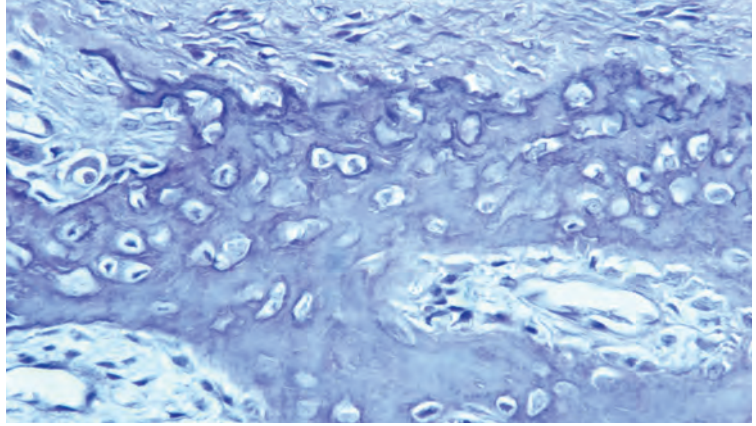
PHI

nanoTOF II

Time-of-Flight Secondary Ion Mass Spectrometer

with Parallel Imaging MS/MS for Confident Molecular Identification



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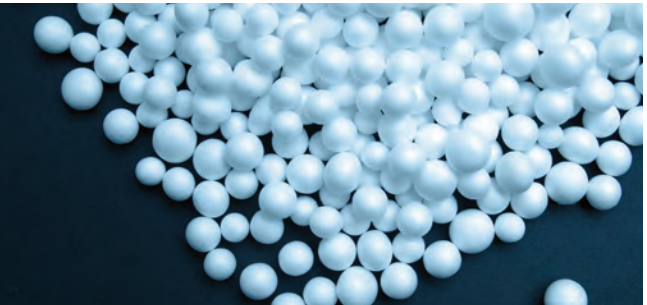


PHI *nanoTOF* II

Designed for Confident Molecular Identification and Superior Imaging

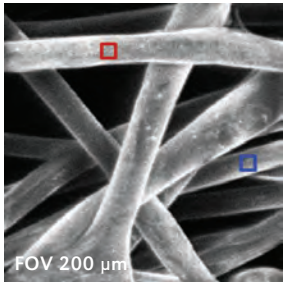
Time-of-flight secondary ion mass spectrometry (TOF-SIMS) is a key analytical technique for detecting, identifying, and imaging the distribution of both elements and organic molecules on the surface of materials. TOF-SIMS is the only imaging mass spectrometry technique that provides less than 70 nm spatial resolution. The PHI *nanoTOF* TOF-SIMS platform has established itself as uniquely capable of providing superior analytical data, even on the most challenging samples. The *nanoTOF* II includes the innovative TRIFT mass spectrometer technology now designed to accept PHI's new and revolutionary Parallel Imaging MS/MS option. This patented option dramatically simplifies TOF-SIMS data interpretation and peak identification without compromising spatial resolution and speed. For the first time, unambiguous identification is possible for high mass molecular ions, transforming peak identification from *"I think"* to *"I know!"*

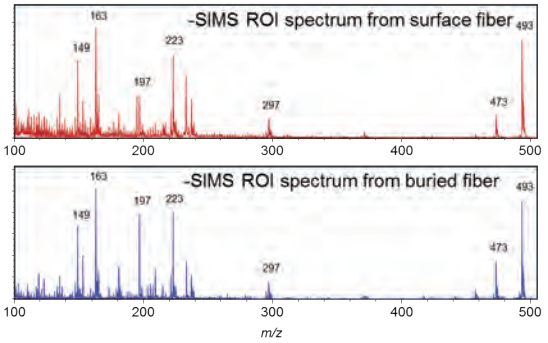
The PHI *nanoTOF* II TOF-SIMS instrument ensures that there are no compromises in analytical performance. It was designed with *"The Power of And"* in mind. This synergistic design optimizes and combines multiple performance metrics into a single mode of analysis. It provides high lateral resolution and high mass resolution simultaneously with the HR^2 mode of analysis. The patented TRIFT spectrometer provides superior imaging of highly topographic samples and high mass resolution spectra with excellent mass accuracy over the entire mass range. PHI's integrated MS/MS option enables unambiguous peak identification and delivers high speed imaging by operating in TOF-TOF mode at 8 kHz. The patented sample stage provides full 5-axis sample motion and active temperature control from sample introduction through analysis. Productivity is maximized with a high level of automation and intuitive software.

TRIFT MASS SPECTROMETER

Accurate Chemical Analysis of All Samples

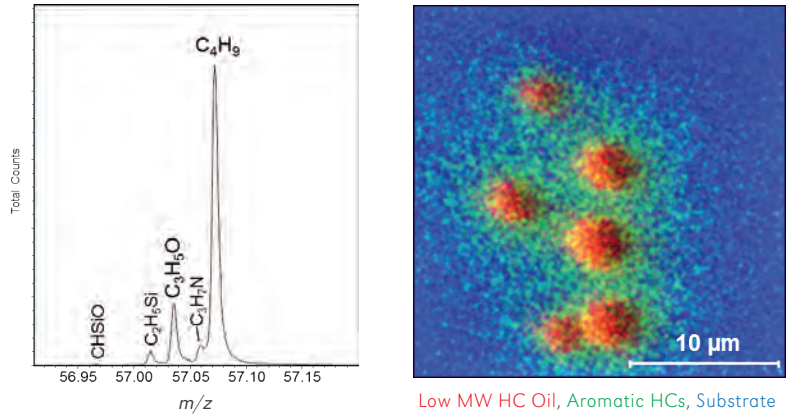
The *Power of And* is very apparent in the uncompromising performance of PHI's TRIFT mass spectrometer. The TRIFT provides high collection efficiency, high mass resolution, high mass accuracy and high signal-to-background spectra, simultaneously, for chemical imaging of flat and rough samples alike. Accurate elemental and molecular imaging of highly topographic, textured and FIB-sectioned samples is a unique capability due to the TRIFT's patented optics design.





A gray-scale total ion image of a non-woven fiber mat. A region-of-interest (ROI) of a surface fiber is highlighted in red, and an ROI of a buried fiber is highlighted in blue. Irrespective of the sample topography and height, the spectral performance is almost identical owing to the exceptional depth-of-field of the TRIFT mass spectrometer.

HR² IMAGING CLUSTER LMIG



Low MW HC Oil, Aromatic HCs, Substrate

The power and utility of HR² mode imaging is exemplified in the surface analysis of micro droplets. In only a 6 minute acquisition the micron-sized droplets are spatially resolved, and the high mass resolution spectrum allows molecular identification.

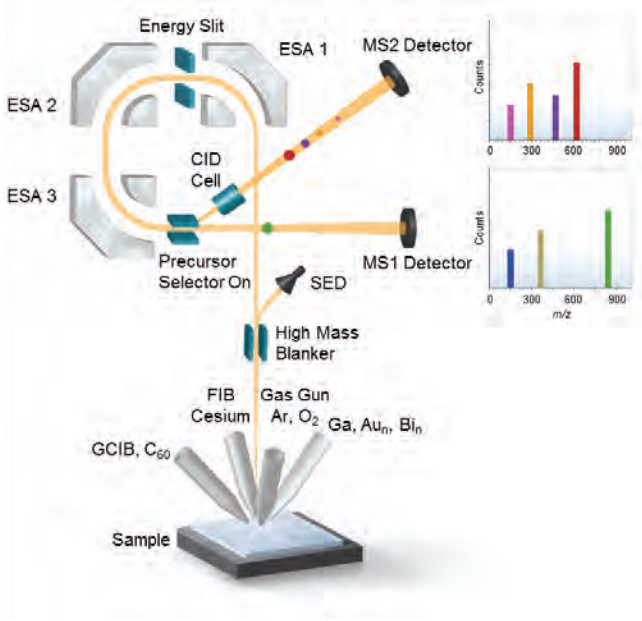
Simultaneous Spatial and Spectral Resolution of Chemistry

The *Power of And* is best illustrated by the new PHI liquid metal ion gun (LMIG). The cluster LMIG is designed to optimize performance in the HR² mode of analysis. This analysis mode provides high spatial resolution imaging and high mass resolution spectra in a single analysis. What's more, the HR² mode is realized using a high analytical beam current so that a typical analysis is conducted in only a few minutes. Now it is not necessary to choose between optimized imaging or spectroscopy; PHI's unique HR² mode of operation gives you both in a single rapid analysis.

TANDEM MASS SPECTROMETERS

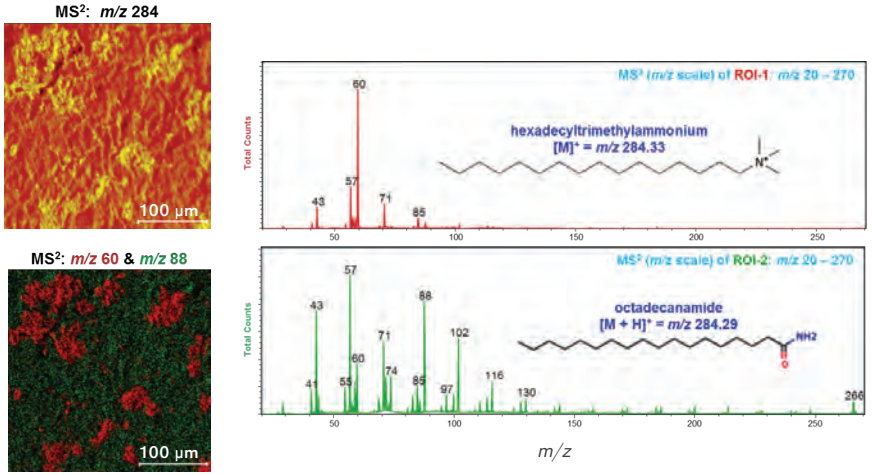
Maximum 2D/3D Information Content

The *Power of And* provides the capability for parallel and synchronous TOF-SIMS (MS^1) and tandem MS (MS^2) imaging. Never before has tandem MS imaging been available at the < 70 nm spatial resolving power provided by TOF-SIMS. The revolutionary and patented PHI Parallel Imaging MS/MS option provides the maximum mass spectrometry imaging information, with unequivocal molecular identification, from any specified analytical region. Since the MS^1 and MS^2 data are collected simultaneously and from the same volume, the MS^1 and MS^2 images are always in perfect registry. The elegant and fully integrated Parallel Imaging MS/MS option provides peak identification and imaging in a single analysis.



The schematic highlights the triple electrostatic analyzer (ESA) design of the *nanoTOF* II's TRIFT mass spectrometer. Selected precursor ions are deflected at high energy into a collision-induced dissociation (CID) cell for fragmentation. The product ions are collected at the MS2 detector. Any ions not within the monoisotopic precursor selection window continue on their original flight path to the MS1 detector.

MOLECULAR ID WITH MS/MS



The power of Parallel Imaging MS/MS for molecular identification via tandem MS imaging is demonstrated in the chemical separation of two precursor ions both having a nominal *m/z* of 284. In only a 10 minute acquisition, each molecular component is easily observed in the MS^2 overlay shown in the lower left image. Mass spectra are generated from each region-of-interest (ROI), comprised of either the red or the green pixels, and the corresponding spectra are shown to the right. The composition and identification of each molecule is made by reference library matching.

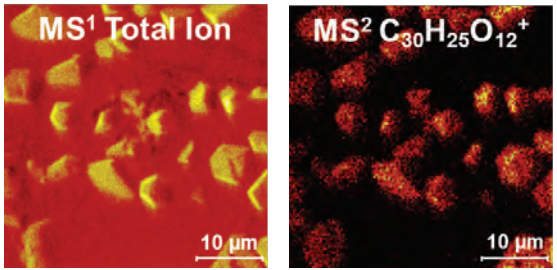
Simplified TOF-SIMS Peak Identification

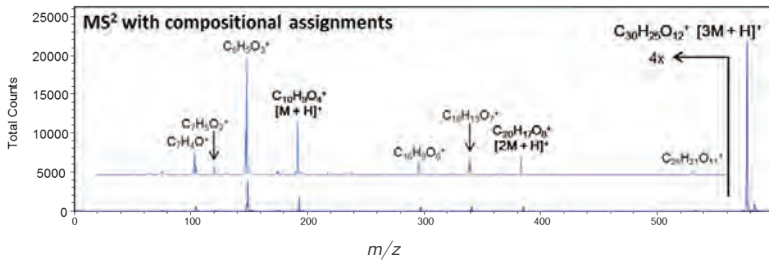
The *Power of And* delivers superior molecular identification, structural elucidation and imaging within a tandem MS analysis. PHI's patented Parallel Imaging MS/MS option enables the production of pure, single-molecule spectra from the complex mixture spectrum which greatly simplifies data interpretation and peak identification. Molecular identification and imaging are achieved at the highest sensitivity; therefore, one-of-a-kind samples may be probed repeatedly for identification of numerous molecular precursors. PHI's new Parallel Imaging MS/MS option takes TOF-SIMS peak identification from "I think" to "I know!"

PARALLEL IMAGING WITH MS/MS

High Speed Surface Imaging and Identification

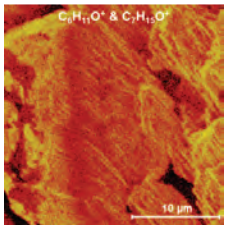
The *Power of And* was incorporated into PHI's Parallel Imaging MS/MS option in order to make it practical and simple to use. It was designed to address molecular identification at high lateral resolution and to operate at the same high repetition rate (> 8 kHz) used for TOF-SIMS analysis. The MS/MS hardware and software are fully integrated with the *nanoTOF* II for simplicity of analysis. The high sensitivity of PHI's Parallel Imaging MS/MS option provides the only available capability that can ensure tandem MS analysis of only the outermost surface molecules.

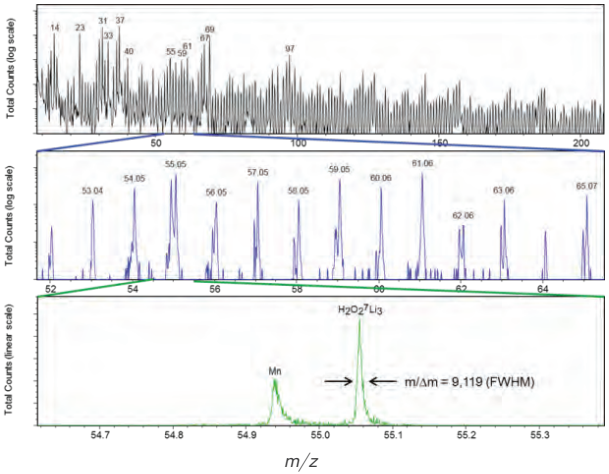




The utility and effectiveness of Parallel Imaging MS/MS is demonstrated in the analysis of surface precipitates on heat-treated poly(ethylene terephthalate) (PET). In only a 13 minute acquisition the 3 to 7 µm precipitates are observed and the tandem mass spectrum clearly identifies the molecular composition of the precipitates. The lateral resolution in both the MS^1 and the MS^2 images is measured to be < 200 nm.

FIB-TOF IMAGING





A TOF-SIMS image, collected in 5 minutes using the HR^2 mode of analysis, of a FIB-sectioned lithium ion battery anode showing the distribution of $C_6H_{11}O^+$ (*m/z* 99) and $C_7H_{15}O^+$ (*m/z* 115) ions. The lateral resolution was measured to be ≤ 150 nm in both ion polarities. The spectra demonstrate excellent signal-to-background and high mass resolution for full chemical and isotopic characterization.

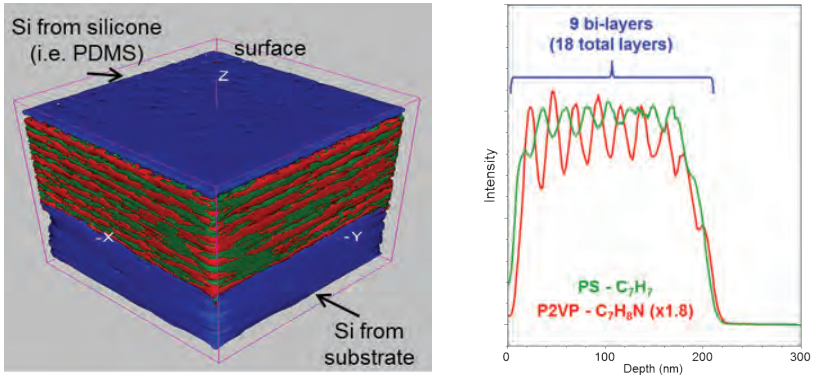
2D/3D Characterization of Challenging Specimens

The *Power of And* ensures that *in situ* sectioning and 3D tomography, via the dedicated PHI FIB option, can easily be performed and allows for superior TOF-SIMS analysis of the sectioned surfaces. Porous and multi-phase materials which are not amenable to traditional sputter depth profiling are readily characterized by FIB-TOF analysis. Full range mass spectra collected at high mass resolution, high mass accuracy and with excellent signal-to-background (S/B) enable robust chemical imaging of the FIB sidewall. The quality of the spectrum over the entire analytical mass range, combined with uniform collection efficiency over the depth of the FIB section, provides an unmatched capability for high resolution 2D and 3D imaging.

GCIB CLUSTER ION BEAM

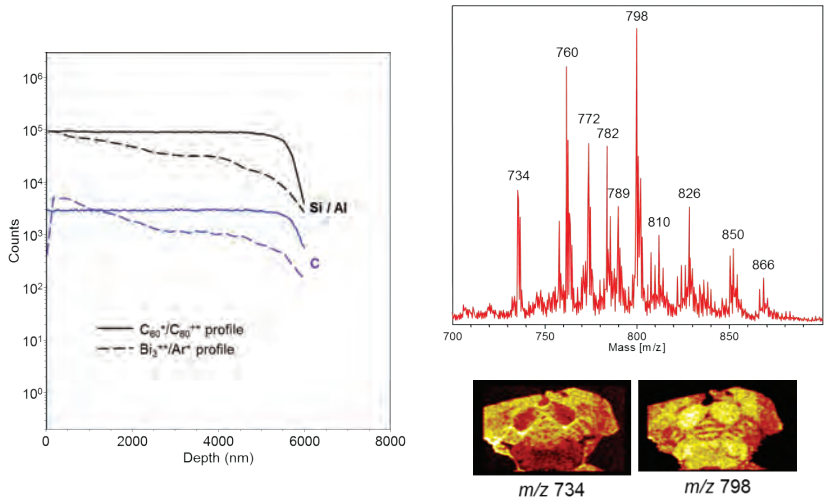
Non-Destructive Organic Depth Profiling

The *Power of And* equips the analyst with tools for in-depth, non-destructive characterization of organic and molecular specimens without sacrificing resolution or molecular specificity. The PHI gas cluster ion beam (GCIB) option may be used for surface cleaning prior to analysis and for rapid 3D characterization to tens of microns in depth. For the characterization of multi-layer materials, the ultimate layer resolution may be realized while also making full use of the HR^2 mode for high resolution molecular imaging.



A depth profile of a poly(styrene)/poly(2-vinyl pyridine) (PS/P2VP) copolymer blend approximately 200 nm-thick on a Si substrate. The profiles and 3D image data expose the 3-dimensional structure and composition.

C_{60} CLUSTER ION BEAM



(LEFT) Depth profiles of a 6 µm-thick aluminosilicate sol-gel on copper by Ar and C_{60} sputtering. The C_{60} ion beam does not produce the differential sputtering artifacts produced by the Ar ion beam. Additionally, the C_{60} analysis beam does not produce the surface transient artifact that is produced by the Bi analysis beam.

(RIGHT) The C_{60} analysis beam delivers the greatest sensitivity for molecular imaging as demonstrated by the spectrum and maps of molecular lipids in a coronal rat brain cross-section.

Profiling and Imaging with Minimum Artifacts

The *Power of And* provides advanced tools to address and resolve complex analytical problems. The PHI C_{60} gun option is a uniquely effective beam for sputter depth profiling of inorganic and mixed composition materials and may be used in an interleaved fashion as a beam for analysis. Interface transients and differential sputtering are greatly reduced with C_{60} compared to monatomic sputter ion beams. Additionally, the use of C_{60} for analysis provides 50x – 100x higher signal compared to Au_3 and Bi_3 due to reduced beam-induced damage.

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Standard Features

- TRIFT mass analyzer
- 30 kV LMIG with Bi, Au, or Ga emitter
- Dual beam charge neutralization
- 5 axis sample stage
- *In situ* optical viewing
- Secondary electron detector
- SmartSoft-TOF instrument control and TOF-DR data reduction software packages
- Analysis chamber with four primary ion gun ports
- 350 l/s turbo molecular pump
- Integrated bakeout facilities

Optional Accessories

- Parallel Imaging MS/MS
- 20 kV C_{60} pulsed ion gun
- 20 kV Ar_{2500} gas cluster ion gun
- 2 kV Cs ion gun
- 5 kV gas gun (Ar/O_2)
- Oxygen flood module
- 30 kV Ga FIB gun
- Hot/Cold sample stage module
- Flash cooling for sample intro chamber
- High temperature sample stage module
- Fast sample rotation module
- Sample transfer vessel
- Intro chamber glove box
- Voltage cycling sample stage module
- Sample preparation chambers