Introduction

Organic based nano-contaminants are a common defect type found in micro-electronics manufacturing processes, including semiconductor, data storage, and LED. These types of organic contaminants are a serious defectivity issue for manufacturers as they cause yield issues, process delays and can lead to scrap product.

The contaminants arise from a variety of sources, including chemical processing, cleaning techniques, airborne molecular contamination, wafer transfer and handling, as well as the degree of human interaction with the processes. Significant efforts are expended in the prevention and detection of defects. Despite these efforts, critical or unknown defects still occur and require off-line characterization.

For many of these defects, there is still a significant class, including organic nanocontaminants, where unambiguous identification is difficult to obtain using existing instrumentation, due to insufficient resolution or even damage to the sample during measurement.

Abstract

Organic nano-contaminants are a serious defectivity issue for semiconductor and data storage companies where current characterization techniques have limited capabilities. This note describes the application of the nanoIR2-FS™ to the measurement of such defects. The nanoIR2-FS system is based on a scientific breakthrough technique of acquiring IR spectra at spatial resolutions down to sub 20 nm, enabling researchers to obtain nanoscale chemical fingerprints of their material. The spectra generated using Anasys Instruments’ patented AFM-IR™ technique correlate extremely well with traditional FT-IR spectra, and are thus comparable to standard IR libraries. In addition to chemical analysis, the nanoIR2-FS provides complementary mechanical, thermal, and structural property information with nanoscale spatial resolution.

Key words

AFM-IR | Nanoscale IR spectroscopy | Organic nanocontamination | Critical defects | Data storage hard disk media
Comparison of existing techniques.

Many different types of instrumentation and measurement techniques are used in the Failure Analysis environment, each with their own benefits and drawbacks. The table below provides a general comparison of techniques specifically for the measurement of organic contaminants.

The nanoIR2-FS™ with FASTspectra™ provides a unique, non-destructive way to measure these types of defects, and provide unambiguous chemical identification with nanoscale spatial resolution.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Resolution</th>
<th>Strength</th>
<th>Limitation</th>
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<tbody>
<tr>
<td>XPS</td>
<td>&gt;1mm</td>
<td>High sensitivity</td>
<td>Low spatial resolution</td>
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<td></td>
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<td>Surface specific technique</td>
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<tr>
<td>SIMS</td>
<td>~0.1-1mm</td>
<td>High surface sensitivity</td>
<td>Rich dataset needs complex analysis</td>
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<td></td>
<td>Good resolution</td>
<td>Expensive technique and</td>
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<td>High cost of ownership</td>
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<tr>
<td>SEM/EDX</td>
<td>~10-100nm</td>
<td>High resolution</td>
<td>Limited to elemental analysis.</td>
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<td></td>
<td></td>
<td>Quantitative elemental analysis</td>
<td>Not very useful to identify complex organics.</td>
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<tr>
<td>Nanoscale IR spectroscopy</td>
<td>~20-100nm</td>
<td>High spatial resolution and high sensitivity</td>
<td>Limited sensitivity to inorganic materials.</td>
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<tr>
<td>(Resonance enhanced AFM-IR)</td>
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<td>Sensitive to organics</td>
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<td></td>
<td></td>
<td>Direct correlation to FTIR libraries</td>
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<tr>
<td>IR spectroscopy</td>
<td>3-5 microns</td>
<td>Unambiguous identification of organic materials</td>
<td>Resolution limited to approximately 3µm.</td>
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<tr>
<td>Confocal Raman</td>
<td>400-600nm</td>
<td>High spatial resolution for spectroscopy</td>
<td>Limited spectral libraries and limited spectral quality.</td>
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Application examples

Bare silicon wafer

Figure 1. Image: AFM height image (a) and corresponding AFM-IR spectra (b) of organic residue on a silicon wafer show clear Amide I and II bands, indicating human skin residue. Colored line spectra corresponded to colored measurement pixels in the AFM image.
Detecting polymeric materials in chemical processing

A wide range of polymeric materials are used in micro-electronics manufacturing processes and can appear as defects. These contaminants can lead to yield loss and impact performance. AFM-IR provides detailed spectroscopic information about the materials to help resolve manufacturing issues.

Figure 2: AFM height image (a) and resulting nanoIR spectra (b) from contaminant on bare silicon wafer. Resulting match from the FTIR library identifying the contaminant as Poly(ethylene terephthalate).

Figure 3: AFM-IR spectra (1000-1800cm⁻¹) of polyethersulfone (PES) showing high resolution spectra with characteristic peaks. AFM height image shows location of measured spectra. Analysis with FTIR database confirms the spectral assignments. S = O sym. stretch: 1152, 1295, CSO₂C asym. stretch: 1320, C-O asym. stretch: 1000-1240 and Benzene ring stretch: 1485, 1578 and finally Carbonyl: 1731.
AFM-IR technique

Infrared (IR) spectroscopy is one of the most recognized analytical measurement techniques in academic, government, and industrial R&D and failure analysis laboratories for the characterization of polymeric materials. However, the spatial resolution of conventional bulk IR spectroscopy is limited by Abbe diffraction laws to between 3 – 10µm, depending on the method used.

Atomic Force Microscopy (AFM) is a widely used nanoscale imaging technique that provides the user with a high spatial resolution topographic map of a sample surface. Until now, the major drawback of AFM is that it fails to chemically characterize the material underneath the tip. However, when AFM is combined with an IR source, the resulting AFM-IR technique breaks the diffraction limit of conventional IR spectroscopy by orders of magnitude, while still providing the high resolution imaging capabilities of AFM.1

In the AFM-IR technique, the beam from a pulsed, tunable IR laser is automatically guided onto a sample surface that is also co-located with the AFM tip. When the IR laser source is tuned to a wavenumber for which there is a corresponding molecular vibration present in the sample, the rapid thermal expansion due to heating induces an oscillation of the AFM cantilever. The amplitude of the oscillation of the cantilever can be recorded at a specific site while the laser wavelength is scanned over a desired range producing AFM-IR spectra. A schematic diagram for AFM-IR is shown in figure 4.

AFM-IR spectra can be directly correlated to traditional bulk FTIR data, as the amplitude of the cantilever oscillation is directly proportional to the absorption coefficient of the sample. This means that spectra of unknown materials can be searched for in an existing FTIR database for definitive identification. Similarly, the same tip can be scanned over an area of interest while the IR laser is tuned to a single wavenumber, thus yielding an IR image that shows the chemical distribution with sub 50 nm spatial resolution.

Soft samples such as organic matter on hard substrates like silicon, slider, and disk media are ideal applications for nanoscale IR spectroscopy. nanoIR also provides chemical imaging and mapping capabilities, allowing researchers to expand their failure analysis capabilities.

Figure 4: Schematic diagram showing the operating principal of the AFM-IR technique.
NanoIR2-FS nanoscale IR Spectroscopy Overview

The nanoIR2-FS is the most advanced nanoscale IR spectroscopy, chemical imaging, and materials property mapping system for industrial environments. It uniquely provides spectroscopic capabilities with direct correlation to FTIR transmission spectra on a wide range of material types, enabling nanoscale FTIR spectroscopy.

**Highest spatial resolution and monolayer sensitivity**

Anasys’ patented Resonance Enhanced AFM-IR™ technology sets new standards in resolution, achieving the highest IR spatial resolution, while maintaining monolayer sensitivity. This unrivaled resolution is achieved in combination with the highest spectral resolution, resulting in the most complete performance of IR characterization capabilities available on any platform.

**FASTspectra™ - high speed spectra in seconds**

A proprietary technology providing nanoscale FTIR spectra in seconds, FASTspectra laser technology extends Resonance Enhanced AFM-IR to a wider spectroscopic range to include the O-H, C-H stretch and N-H stretch regions, setting new standards of resolution and sensitivity for a broader set of applications while still providing unrivaled, direct correlation to FTIR at the nanoscale.

**Multi-modal imaging – simultaneous nanoscale material property mapping**

An integrated, fully featured AFM provides unique property mapping capabilities with thermal, mechanical, and electrical modes to support multi-modal characterization of a wide range of materials science and life science applications. Additionally, our nanoIR2-FS™ provides expanded applications coverage with optional environmental and temperature control.
Highest resolution, high speed chemical imaging

The nanoIR2-FS also provides high speed, high resolution IR based chemical imaging to provide mapping of chemical variations of a feature of interest. Our patented Tapping Mode AFM-IR™ chemical imaging technique quickly and easily creates chemical mapping of the highest spatial resolution. Whether your goal is creating chemical composition maps of polymers or to image the smallest, thinnest contaminants, obtaining high resolution chemical imaging has never been this easy and fast.

Proven productivity on real world samples

The nanoIR2-FS is has been designed with ease of use and time to data in mind to meet the needs of industrial users.

Unique automation and productivity features eliminate the need for complicated laser alignments and enables users to become productive within a day.

Industrial users comprise over 30% of our installed base. The nanoIR product has been adopted by leading industrial companies to help solve critical processing and materials related problems, including semiconductor, data storage and chemical processing companies.

References


Contact us today to see how nanoIR spectroscopy can help your company.