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### Application Note #150 Characterization of Advanced Semiconductor Materials and Processes with Nanoscale IR Spectroscopy

Substratum and nanoscale chemical identification of semiconductor materials, specifically those that are organic, is a significant challenge in the research of devices, as well as in process control and failure analysis environments. Because of this, there are a multitude of techniques used by semiconductor manufacturers to identify chemical components.

Scanning electron microscope coupled with energy dispersive X-ray spectroscopy (SEM/EDX) is the industry standard in surface analysis, and offers nanoscale spatial resolution with semi-quantitative elemental analysis. While this elemental analysis offers useful chemical insight into surface defects and contaminants, it is fairly limited in identifying organic materials.

Infrared (IR) spectroscopy is a powerful technique for chemical characterization of organic species that cannot be readily identified by SEM/EDX. However, traditional IR spectroscopic techniques are limited by Abbe diffraction limits to spatial resolutions between 2-10 µm, depending on the technique used.

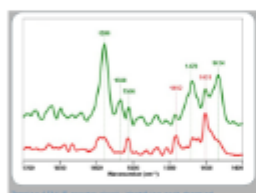
Atomic force microscopy (AFM) is a widely used nanoscale imaging technique which provides the user with a high spatial resolution topographic map of a sample surface. Until now, the major drawback of AFM has been its inability to chemically characterize the material underneath the tip.

#### Resonance-Enhanced AFM-IR and Tapping AFM-IR

Nanoscale IR spectroscopy overcomes these limitations by combining AFM and IR techniques to achieve nanoscale FTIR spectroscopy using photothermal IR spectroscopy (PTIR). Nanoscale IR spectroscopy combines the precise chemical identification of IR spectroscopy with the nanoscale capabilities of AFM to chemically identify sample components with a spatial resolution below 10 nm and with monolayer sensitivity, breaking the diffraction limit by ~100x. AFM-PTIR absorption spectra are direct measurements of sample absorption, independent of other complex optical properties of the tip and sample. As such, AFM-PTIR spectra correlate well to conventional bulk IR spectra.

#### Nanoscale Organic Contaminants

To demonstrate nanoscale chemical characterization capabilities on the nanoscale, contaminated silicon wafers were first prepared using known materials typical of those found in semiconductor fabrication environments, and then analyzed. For each sample, high-resolution tapping mode



Tapping mode IR spectra using scanning photothermal microscopy of a dual-layered material.

## Characterization of Advanced Semiconductor Materials and Processes with Nanoscale IR Spectroscopy

This application note demonstrates the successful application of Tapping AFM-IR to distinguish the chemical footprints of several nanoscale lithographic patterns consisting of complex molecular assemblies with excellent spatial resolution of 4 nm. Additionally, nanoscale IR spectroscopy also excels in the characterization of nanoscale defects.

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