

Diagnostic Capabilities of the Ion Beam Laboratory

Pelletron 1.7MV Tandem Accelerator and Beam Lines

The Ion Beam Laboratory at the University of Wisconsin-Madison houses a dual source tandem 1.7MV terminal electrostatic ion accelerator. With the capability of producing stable, monoenergetic beams (from 500 keV to 5 MeV) of practically any element in the periodic table, the Ion Beam Laboratory is capable of a wide range of ion beam materials diagnostic capabilities. Some applications of these techniques include thin film analysis, interface diffusion analysis, surface analysis, and radiation damage in materials. The following sections will overview the fundamentals and applications of the lab's diagnostic capabilities.

Rutherford Backscattering Spectrometry – RBS

Rutherford Backscattering Spectrometry using ion beam energies in the MeV range can be performed to accurately determine stoichiometry, elemental areal density, and impurity distributions in clean material samples. In thin films on the order of microns thick, properties such as thickness, density, and interfacial diffusivity can be determined, however film thickness and density are closely linked, and a good knowledge of one is needed to determine the other. Another fallback of this method includes a general insensitivity to light elements ($Z \leq 11$), especially as impurities in a high-Z matrix. On the contrary, many light elements can be profiled due to non-Rutherford scattering cross-sections, and high-Z impurities are readily visible in concentrations less than 10 ppm. Mass resolution among elements is generally limited by resolution of the detector, but is typically accurate to <1%.

Elastic Recoil Detection – ERD

Elastic Recoil Detection in many ways complements RBS. Working on the principle of detecting forward-recoiling target atoms, it is a simple scattering detection method used for the detection and depth-profiling of light elements ($1 \leq Z \leq 9$). ERD finds itself most effective at detecting hydrogen and its isotopes, since high performance beams of alpha particles are readily available and attribute to good depth scale and resolution. ERD is the technique of choice for light element profiling applications because of the simplicity, possibility of simultaneous multi-element profiling, fair sensitivity, and good depth resolution.

Nuclear Reaction Analysis – NRA

There are several methods of Nuclear Reaction Analysis, all relying on inducing energy-dependent nuclear reactions between light elements and detecting the reaction products. The technique is isotope-sensitive, making isotope tracing experiments very easy, and generally uses either proton, deuteron, He^3 , or alpha particle beams to induce particle- and gamma-producing nuclear reactions in light elements. Often reactions with very narrow energy dependent cross section resonances, or interaction probability peaks, can be used to depth profile elements with high sensitivity and near-surface depth resolution. Although the method is capable of detecting extremely small quantities of carefully chosen tracer or impurity elements, the composition of the target usually cannot be measured with a single measurement.

Material Modification

In addition to the diagnostic techniques discussed above, the Ion Beam Lab has the ability to modify sample surfaces by source atom implantation. Virtually any element in the periodic table can be accelerated and implanted, to depths ranging from a few nm to over 20 μm (depending on energy and species). The ion beam can be rastered at high frequency to uniformly irradiate large surface areas, up to roughly four inches diameter. Ion implantation is often used to create depth markers in virgin samples that can be easily recognized and serve as constant references throughout later experiments.

MultiPort Multi-Channel Analyzer capability

Recently added to the Ion Beam Lab is a multi-port multi-channel analyzer capable of simultaneously registering up to six independent detectors. This allows for the simultaneous measurement of RBS, ERD, and various NRA spectra, speeding up data acquisition time and enabling thorough surface composition and depth profiling snapshots during dynamic surface evolution experiments.