Rutherford Backscattering Spectrometry

HOW DID WE GET HERE?

Linear Particle Accelerator

In order to support their research on transmutation of atomic nuclei, John Douglas Cockcroft (pictured) and Ernest T.S. Walton from the University of Cambridge developed the first linear particle accelerator allowing high intensity controllable beams. This work was recognized by the Nobel Prize in 1951.

Surveyor 5

By performing a backscattering experiment from the moon, NASA Surveyor 5 mission brought mass media attention to RBS. The aim was to quantify the major elements on the surface of the moon.

1911

1932

1955-1965

1967

1973

Gold Foil Experiment

Starting in 1909, Ernest Rutherford, born in New Zealand in 1871, initiated some experiments at the Cavendish Lab (University of Cambridge) showing the nuclear structure of matter. In 1911, his research lead to a 1911 publication establishing the nuclear model of the atom.
(see below for details on the gold foil experiment)

Surface Barrier Detector

Various labs including CEA (France), Chalk River (Canada) and Oak Ridge (USA) worked on the development of Surface Barrier Detectors also known as Silicon Surface Barrier (SSB). By replacing Magnetic Spectrometers, SSD simplified the acquisition of data in RBS experiments.

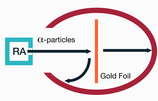
ECS Chicago

Due to the development of the technique, the Electrochemical Society asked several labs including Cornell to present their research on back scattering techniques. RBS was no longer a specialized nuclear technique but was becoming a standard analytical method.

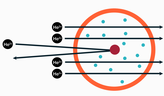
*Reference: Rutherford backscattering spectrometry: reminiscences and progresses . W.K. Chu,J.R. Liu . Materials Chemistry and Physics, 1996

The Gold Foil Experiment:

Starting in 1909, Hans Geiger (that would later invent and give his name to the radioactive counter) and Ernest Marsden from the Rutherford lab put together an experiment to study the behavior of α-particles (He^{2+}) when interacting with gold.



The theory predicted that all the alpha particles would go through the gold with some possible deflection. The experiment showed that 1/20,000 α-particles bounced back. For Rutherford, "it was almost as incredible as if you fired a 15 inches shell at a piece of tissue paper and it came back and hit you".
From this experiment, in 1911, Rutherford proposed a new atomic model, the nuclear model, that would contradict the current plum pudding model of JJ. Thomson. In the center of the atom, there has to be a something very small, very heavy and positively charged: the nucleus.



Atomic Level View (Nuclear Model)

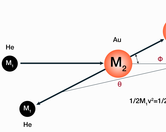
HOW DOES IT WORK?

Rutherford Backscattering (GC)

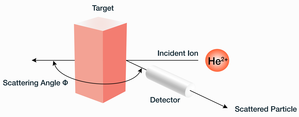
Have you ever wondered what it would be like to look down at a surface and see down to the level of an atom? Our entire existence is influenced by how the atoms around us are arranged. From the transparency of glass in windows to the processor speeds in servers, it is important to precisely measure the placement and composition of atoms.

Why engineers need RBS for materials analysis?
Many engineers (process, materials, integration, and failure analysis) struggle to know what is the structure and composition of the material that they deposited. Are the layers pure? How thick are the layers? Is there intermixing? A host of analytical tools exist to answer these questions but most of the tools only yield surface information 1 – 10 nm. There are depth profiling tools such as XPS, AES and SIMS that can give depth profiles but they require drilling into the samples with high energy gas through a process known as sputtering. This sputtering can cause fine atomic structure to mix resulting in process induced artifacts. This brings us to our focus for the month, Rutherford Back Scattering (RBS).

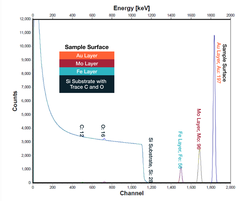
What information does RBS give?
This will serve as a high-level overview of RBS to convey basic theory, system setup and basic data interpretation. The actual data is modeled using detailed physics programs that can handle complex structures. For a simple case where the heaviest elements are nearest the surface, the analysis can be more easily explained.



RBS is a distinctive technique that can probe from the surface (1nm) to ~ 1 micron deep and provide compositional analysis (to about 1 atm %) along with atomic packing density and even crystallographic defect detection. RBS does not require a reference samples for compositional analysis because the technology is based on collision physics. RBS works by directing high energy ions, usually Helium (He), at the sample, such as a gold (Au) foil on a silicon substrate. The helium deflects off the gold. Angle and energy of the backscattered Helium are used in the physics modeling to determine which type of atom (M2) matches the collision equation. This process is repeated by measuring the position and energy of all the backscattered helium ions resulting in accurate location and atomic composition throughout the sample.

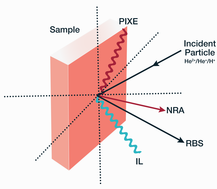


Reading RBS Spectra



Typical RBS spectra are presented as Counts (total counts detected by the detector) and Channels. Channels are bins for the histogram of energies and they have a correlation to the energy of the backscattered helium. Higher energy helium (higher channel number) will tend to be from heavier elements near the surface. The higher the count and wider the channel number the denser and thicker the layer is respectively in the sample. If the structure has small pockets of other elements the signals will superimpose such as C and O signals on top of the Si signal as shown in the example RBS spectra.

Additional Analysis



APPLICATIONS

RBS Analyze non-destructively thin film composition up to 1 µm

HFS Measure hydrogen profile in thin films and bulk materials

NRA Measure specific isotopes for high accuracy composition of elements such as B, C, N and O

PIXE Study the X-rays released by the sample, good for trace contamination detection

IL Study photons emitted by electron-hole pairs recombining, useful for locating and identifying types of crystal dislocations

WHY CHOOSE OUTERMOST TECHNOLOGY FOR RBS?

Fast Turnaround Time, Data Report Within 4 days of Sample Receipt
- Samples can be pre-diced or diced onsite further saving your time

Competitive Pricing - RBS/HFS
- Commonly used for analyzing hydrogen profiles for samples on silicon
- Can distinguish hydrogen in the various layers of a film stack
- Also used to verify deposition quality and monitor carbon content

Great Combination Deal - RBS/HFS/NRA
- NRA is often used to distinguish B and C in depositions
- Combining NRA and HFS further improves the accuracy of the RBS modeling
- Additional NRA options available, please inquire for more details