Rutherford Backscattering Spectrometry, RBS

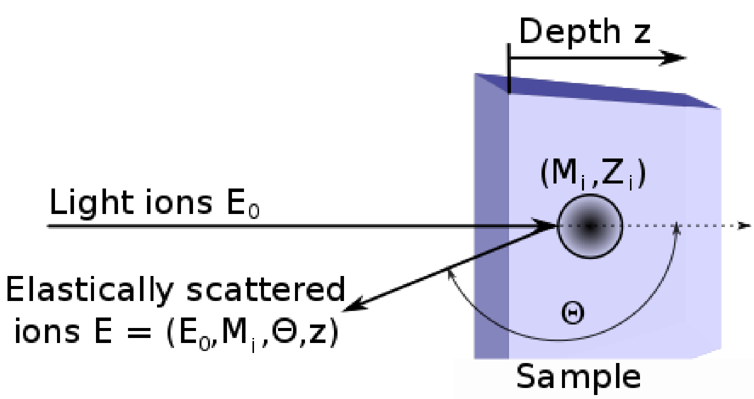
Rutherford Backscattering spectrometry (RBS) is most commonly used non-destructive nuclear analytical methods. RBS is widely used for study of thin layers and for study of multilayer systems with thickness from nm to µm. RBS is very suitable for elemental depth analysis. From such measurement it is possible to determine, with some limitations, both the atomic mass and concentration of elemental target constituents as a function of depth below the surface.

Measurement with this method may be performed on amorphous as well as crystalline materials. It involves measurement of the numbers and energy distribution of energetic ions (usually MeV light ions such He^+) backscattered from atoms within the near-surface region of solid targets. Ions for RBS are usually light ions (H^+, He^+) with energy units MeV.

Energy of backscattered ions, which we detect, is connected with energy loss in scattering on the elements nucleus and with the energy loss of ions between passing through the sample. The RBS detection limit is between $10^{11} – 10^{15}$ at.cm^{-2}. RBS depth resolution is an average of 5 nm.

Features of RBS:

- high sensitivity for heavy elements on a light substrates
- good detection sensitivity for light elements in a heavy matrix only in special cases



- good depth resolution (average 5 nm)

Parameters of RBS:

- ions: H^+, He^+
- energy of ions: order of MeV
- detection limit: up to 1mg/g
- depth range: about micrometer

Theory of RBS

Sample is irradiated with light ions (usually 2-3 MeV (H^+or He^+)) and the elastically backscattered projectiles at large angles are detected. The mass of the target atoms could be identified from the energy of the backscattered projectile. The backscattered particles are detected by the semiconductor detectors Si(Au), the accessible depth 2-10 mm. The heavy element detection limit in the light matrix is up to 1mg/g. The lower mass causes higher transferred energy. The mass resolution is given by detector energy resolution, the energy and projectile mass.

RBS Instrumentation: Instruments

The three main components of an RBS instrument are a source of helium ions, an accelerator to convert them to high energy alpha particles, and a detector to measure the energies of the backscattered ions. The type of accelerator determines the configuration of the other components. Single-ended accelerators have the ion source floating at high voltage. Electrical isolation of the megavolt potentials is achieved by housing the terminal in a tank filled with an insulating gas, usually SF6. One disadvantage of locating the ion source within the tank is that it is difficult to change or replenish the source.

The tandem accelerator uses a positive terminal located in the center of the device. Negatively charged particles are injected into the accelerator and attracted to the terminal where a stripper element removes two or more electrons from each particle. The positive terminal repels the resulting positive ion back toward ground. Thus the particle acquires energy both before and after the terminal.

The tandem configuration has two important advantages over a single-stage setup. First, lower terminal voltages are required, and second, both the source and the ion exit operate near ground potential. The main disadvantage is that inefficiencies of He- production and charge stripping lower He++ beam current to about 100 nA for a tandem versus 1 mA for a single-ended accelerator. Fortunately, most RBS experiments can only use about 100 nA because of detector limitations. A typical RBS installation uses a tandem accelerator, producing a 2.25 MeV He++ beam by removing three electrons from He- at the + 750 KV terminal.

Unique Advantages

- Non-destructive, quantitative analysis (concentration vs. depth)
- Ability to assess crystalline damage in single crystals
- Good detection limits for heavy impurities in light matrices
- Ability to measure atom density of thin films when thickness is known
- Ability to analyze non-conducting organic or inorganic solids and powders

General applications of RBS

1. Quantitative analysis of thin films
2. thickness, composition, uniformity in depth

3. solid state reactions
4. Interdiffusion
5. Crystalline perfection of homo-and heteroepitaxialthin films
6. Quantitative measurements of impurities in substrates
7. Defect distribution in single-crystal samples
8. Surface atom relaxation in single crystals
9. Lattice location of impurities in single crystals