Rutherford Backscattering Spectrometry (RBS)

- RBS/ERD
- depth analysis of thin films
- quantitative compositional analysis
- hydrogen determination
- information on crystallinity

RBS is a well-established technique in thin film characterization in which a beam of high energy (2 MeV) helium ions is directed at a sample. The helium ions that are elastically scattered by nuclei in the sample are detected. The higher the mass of an atom that is hit by a helium ion, the higher the energy of the ion will be after backscattering. This results in mass discrimination. By counting the helium ions as a function of energy, the number of atoms of each element present can be determined.

The principle of RBS

Apart from mass information, RBS also provides depth information: during the flight path through the sample the ions lose energy. This energy loss introduces a depth scale in the RBS spectrum. An ion that is scattered at a certain depth experiences an additional energy loss on the way in and out of the target. Thus it ends up with a kinetic energy lower than that of an ion, which experiences a similar backscattering event at the sample surface.

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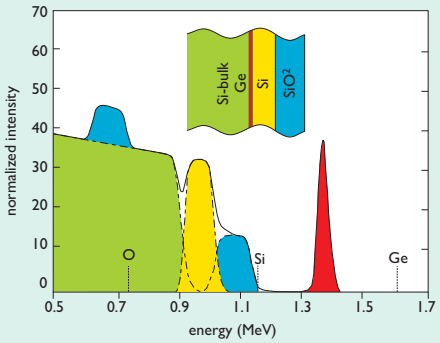

Fig. 1: Example of an RBS spectrum with the x-axis representing the energy scale and the y-axis the relative signal intensity

layer	thickness	
	(*10^{15} At/cm^2)	(nm)
SiO_2	1050	150
Si	650	130
Ge	133	30

Table 1: Thickness in atoms/cm^2 determined from the data shown in Figure 1. By dividing the amount in atoms/cm^2 by the density the thickness is obtained

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An advantage of RBS is that it yields the amount of atoms present quantitatively without the need for any calibration standard. Using RBS, information can be obtained from the surface down to a depth of approximately 1-2 µm without the need for sputtering. This makes the technique fast and eminently suitable for applications in thin film research.
In practice only elements heavier than boron can be detected. However, it is possible to quantify the hydrogen content by measuring the energy of the hydrogen ions, which are scattered forward after being hit by a helium ion. This technique is called Elastic Recoil Detection (ERD).
Furthermore, the crystallinity of samples can be investigated using channeling-RBS.

A typical application

Characterization of a buried germanium layer

An example of an RBS spectrum of a buried germanium layer is given in Figure 1. The sample consists of a silicon substrate with a Ge/Si/SiO_2 layer stack on it. A 2 MeV helium beam is directed at the sample and the energy of the backscattered helium ions is measured.
In Figure 1, the surface energy positions of the elements oxygen, silicon and germanium are indicated by dotted lines. The surface energy position indicates the energy of helium ions back-scattered off an element in the outermost layer of the sample.
The Ge peak (the red peak) shifts towards lower energy (compared to the surface energy position) because of the extra energy loss of the helium ions in the Si and SiO_2 layers on top of the Ge layer. The intensity of the Ge peak is linearly dependent on the amount of Ge. The Si and O signal start at the surface energy position because the SiO_2 forms the top layer. The width of the O and the first Si signal (both blue) both represent the thickness of the SiO_2 layer. At the lower energy side of the first Si signal an additional peak can be observed. This is the Si signal of the pure Si layer (yellow). The width of this peak gives the thickness of the pure Si layer. The signal of the substrate is represented by a continuum instead of a peak, because the Si substrate is infinitely thick for the helium beam (thicker than 2 µm). A summary of the results is given in table 1.

Applications

RBS

- composition of films, multilayers and bulk material
- implantation profiles including dose calibration
- surface and bulk contamination
- interface mixing and reaction
- diffusion profiles

Channeling RBS

- epitaxial growth
- implantation damage
- polishing damage
- lattice location of dopants and contaminants in single crystals

ERD

- hydrogen profiles in thin films

Characteristics

Sample type

- thin films and bulk solids

Sample size

- max. 35x35 mm, min. 5x5 mm

Depth information

- 2 µm for RBS and Channeling
- 0.2 µm for ERD

Lateral resolution

- 1x1 mm

Depth resolution

- 1-10 nm (RBS, Channeling)
- 5-20 nm (ERD)

Mass resolution

- 1 atomic mass unit for Z < 40

Detection limit

- H and elements heavier than B
- substrate and element dependent
- surface sensitivity for nitrogen on top of silicon: 10^{15} atoms/cm^2
- for arsenic on top of silicon: 10^{11} atoms/cm^2
- for gold on top of silicon: 10^{10} atoms/cm^2
- for hydrogen in bulk: 0.1 atom%