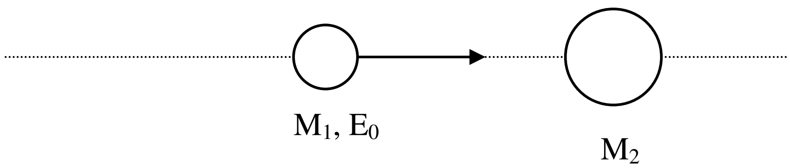
# Brief introduction to Rutherford Backscattering Spectrometry

By Anders Hallén

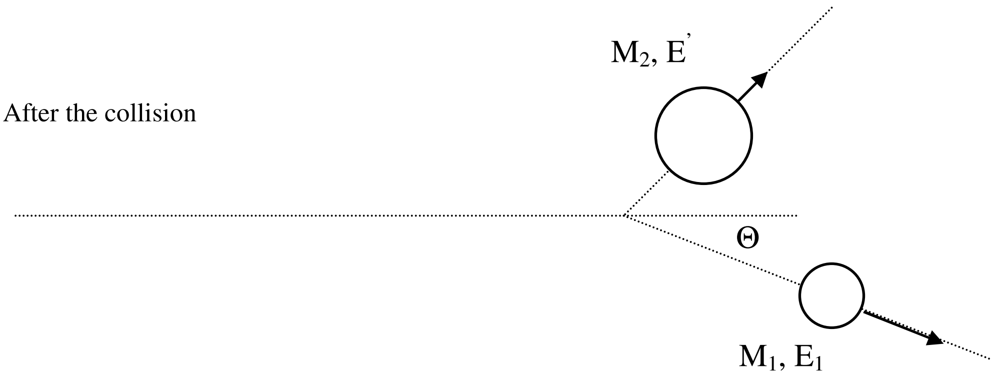
Rutherford backscattering spectrometry (RBS) as a routine technique to address thin film properties in materials research has evolved from nuclear physics experiments conducted during the first half of the previous century. In the 1960's it was developed to a standard analysis technique particularly useful for the growing semiconductor field.

The basic principle is contained in the kinematics for binary collisions. A beam of known particles with mass $M_1$ is given energy $E_0$ and directed onto the sample containing the particles $M_2$ that are to be investigated (see figures below).

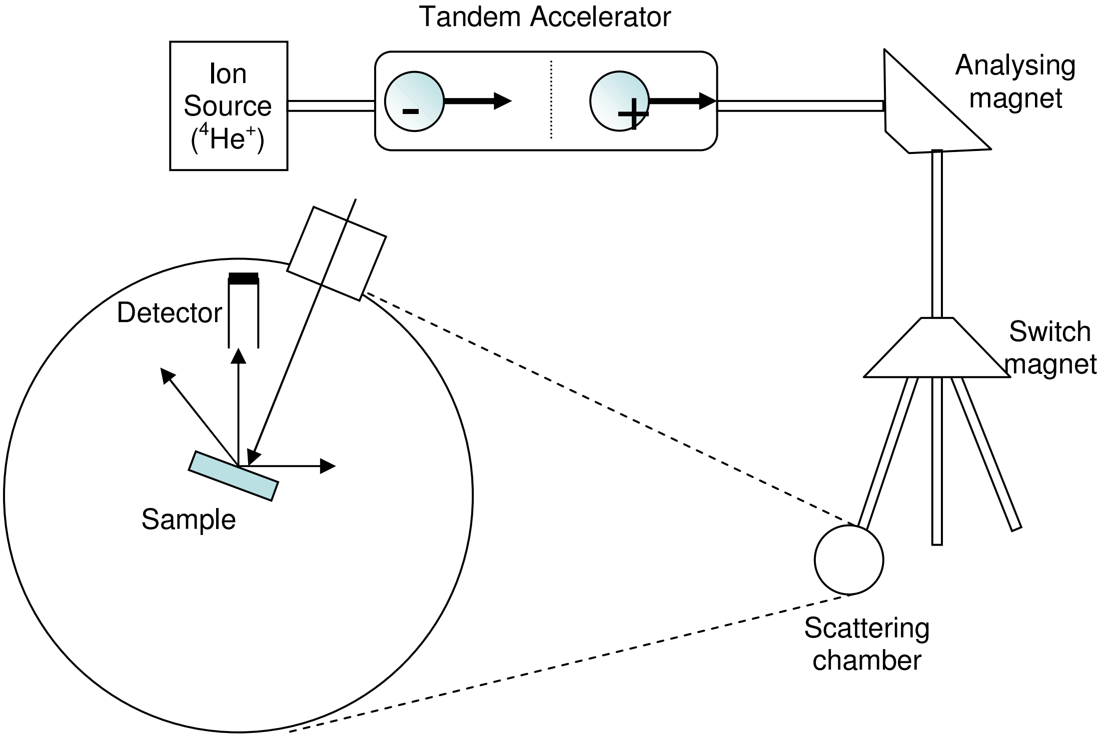
Before the




After the collision

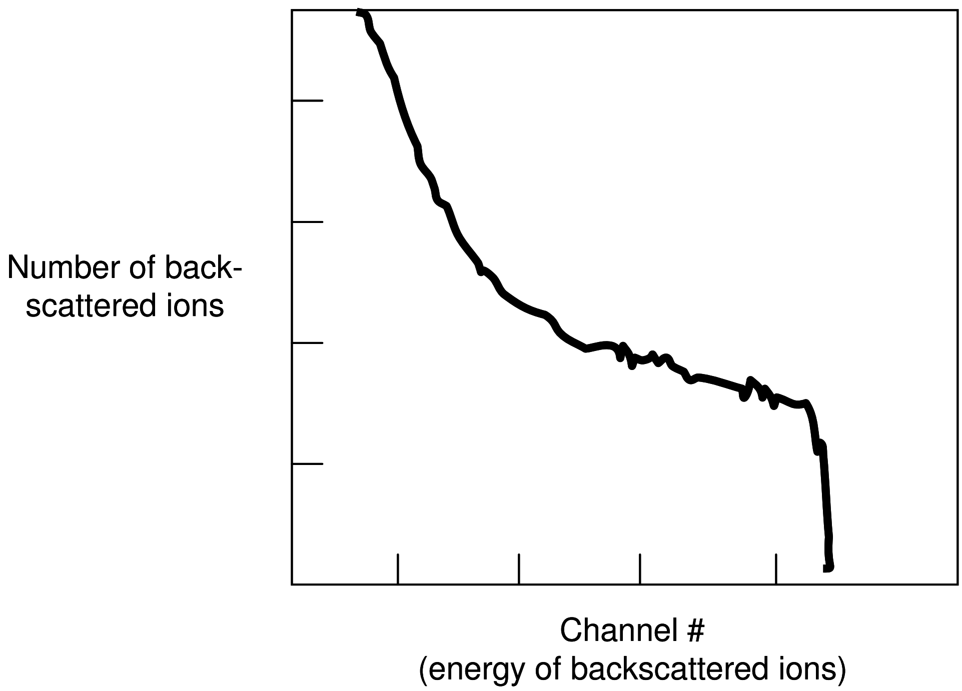



The energy $E_1$ and the angle $\Theta$ of the particle $M_1$ are detected. From the conservation laws of energy and momentum it is then possible to deduce the mass of the target particles $M_2$. Furthermore, since the probability of scattering in a certain angle is known by the so called Rutherford cross section, it is also possible to estimate the abundance of $M_2$ by counting the yield of scattered particles $M_1$ in a certain solid angle covered by the detector. A typical setup (see below) consists of a particle accelerator that can deliver beams of low-mass ions in the MeV range. The beam is about a millimeter in diameter at the target. The detector, a surface barrier detector, is normally mounted in a backscattering angle Θ of for instance 170° from the incident beam. As the incident particles penetrate the target matrix some of them will experience the Coulomb force from target nuclei and be deflected from their path. These collisions are governed by the Rutherford cross section and a small, but sufficient, number of the deflected ions will be backscattered in the detector.




Since the incident low-mass particles loose some of their energy in other processes than elastic Rutherford events, the energy $E_0$ is not well defined at larger sample depths. However, it is possible to estimate the energy loss for the penetrating particles, both on the way in and on the return, and obtain accurate data. In fact, if the matrix is known this energy loss can be converted to a depth scale and in this way the RBS technique can be used to make several micrometer deep profiles of different atomic species.

The spectra (see below for a solid sample containing one element) that are obtained give the yield of backscattered particles as a function of their energy. It is also convenient to collect a calibration spectrum from a sample with known composition. The analysis of spectra is done off line using modern software.




**Questions to be answered before the laboration**

After reading the brief introduction, and using your deep physical knowledge and some imagination, you should now be able to answer the following questions:

1. Explain the different features in the spectrum above.

2. Why is a thin gold film on a silicon matrix much easier to study by RBS than a thin Si film on an Au-matrix?

3. A typical unit for thickness of a film measured by RBS is $cm^{-2}$. How can this be converted to the more reasonable unit nm or µm?

4. Does the sample orientation relative to the incident beam influence the yield of backscattered particles for a crystalline sample?

5. In Uppsala RBS is performed using a 5 MV tandem accelerator where one of the beam lines is equipped with a scattering chamber. What experimental parameters is it possible to control with this setup?

**About the laboration**

We will meet at 10.15 on the day of the lab. outside House 5 in the main entrance hall at Ångström (right after the cafeteria). We will start the day with going through the basics for RBS technique and listen to your answers to the questions above.

Then we will load samples and put the beam on. If you bring your own samples, which I welcome, the ideal format is a square cm chip with a thickness of one or two mm. This part of the laboration is more of a demonstration, since there is only limited room for your practical input. When we have obtained sufficient quality spectra from a few samples, the software used for spectra analysis is demonstrated. At some point we will make a break for lunch and, typically, by three o'clock we are ready.

For your report you need to analyse the spectra and write not more than 4 pages about the RBS technique in general and the Uppsala setup in particular, and also discuss the sample that you have analysed. The software you need for the analysis is free for a month and can be downloaded from the following address:

http://www.physics.isu.edu/sigmabase/programs/simnra44.html

If you need to get in contact with me before I see you in Uppsala my address and numbers are:

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## Further Reading

(A more detailed description of the RBS technique will be handed out to those of you that select this lab.)

W.-K. Chu, J.W. Mayer, and M.-A. Nicolet
Backscattering Spectrometry
Academic Press, New York, 1978

J.R. Tesmer and M. Nastasi (eds.)
Handbook of Modern Ion Beam Analysis
Materials Research Society, Pittsburg, USA, 1995

J.F. Ziegler, J.P. Biersack, and U. Littmark
The Stopping and Ranges of Ions in Solids, Volume 1
Pergamon Press, New York, 1985

L.C. Feldman and J.W. Mayer
Fundamentals of Surface and Thin Film Analysis
Elsevier Science Publishing Co., 1986

## How to get to Uppsala, Ångström Laboratory

You get to Uppsala from Stockholm most conveniently by car. Uppsala is situated about 70 km north along route E4 and it takes less than one hour unless you travel during rush hours. Ångström laboratory is situated in the southern part of the city and to the west of Fyrisån. With a car you exit the highway at "Uppsala S" (first exit),go straight through the first roundabout and continue straight for three trafic lights, you cross Fyrisån and continue up the hill on the other side. At the fourth trafic light you turn right and right again at the next roundabout. Then you will have Ångström parking lot on your right. The distance from the first roundabout is maybe 3 km.

If you go by train, there are trains leaving ever so often from Stockholm central station to the north of Sweden. For instance, "Uppsala-pendeln" leaves every half hour. In Uppsala you can take a bus or a 30-minutes walk to Ångström. Information of the bus transport is found at Uppsala Lokaltrafiks homepage:

http://www.upplandslokaltrafik.se/

An Uppsala map can be found on:

http://www.uppland.nu/turist/eng_index.html