Channeling-ERDA with Heavy Ion Beams

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Channeling-RBS with 2 MeV He ion beams is an often used method for crystalline structure analysis, but there has been only one attempt in the past for channeling-ERDA using heavy ion beams [1]. In principle ERDA (elastic recoil detection analysis) can overcome two major drawbacks of light ion RBS: low sensitivity to light elements and missing particle identification. In the first channeling-ERDA experiment a ToF-detector was used with 0.1 msr solid angle only. Thus the real crystalline structure of some samples was changed during the measurement because of irradiation damage. It was concluded, that a more efficient detector would be necessary for this kind of measurements. The ionization chamber with 6.2 msr solid angle used in our ERDA setup [2] seems to be an appropriate detector and therefore we started a new attempt for channeling in ERDA geometry.

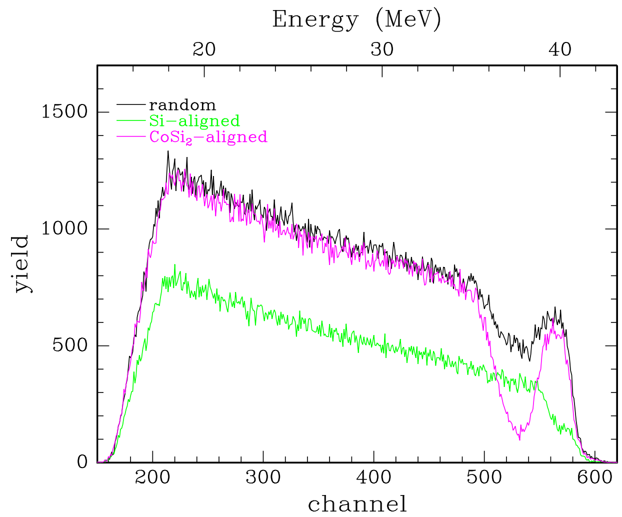

Fig. 1: Random and aligned Si energy spectra of a $CoSi_2$ multilayer sample measured with 150 MeV Ag in ERDA geometry (see text)

Channeling measurements demand some additional features to the standard ERDA requirements. The sample goniometer has to have a rotation possibility around both directions perpendicular to the beam axis to align and tilt a crystal axis precisely to the beam. The accuracy as well as the reproducibility of the rotation should be in the order of 0.01 degree. We have modified our goniometer to have a second rotational axis and measured an angular accuracy of 0.02 degrees. The divergence of the incoming beam has to be of the same order. The usual way of cutting the beam divergence by two collimators some meters apart is not possible in our ERDA beam-line. Thus we tried to restrict the divergence by a special focusing procedure. The measured minimum recoil yield of about 7% for single crystalline Si samples - typical values of 4% are achievable - indicates the need for further improvements of this procedure. For small angle scans around the position of minimum scattering yield a program has to be developed which connects data acquisition and goniometer control. This program has been implemented on our SGI workstation and drives the goniometer via RS232 interface. The program allows automatic scans with predefined beam charge and accumulation of energy spectra in aligned and random position. Here we make use of the particle identification capability of our ionization chamber to separate different components in the sample. Moreover the position sensitivity of our detector allows an easy and unique way for sample alignment by measuring the characteristic blocking patterns of the sample. Alignment of more complex structures would be otherwise a very difficult and time consuming procedure because of the ERDA geometry.

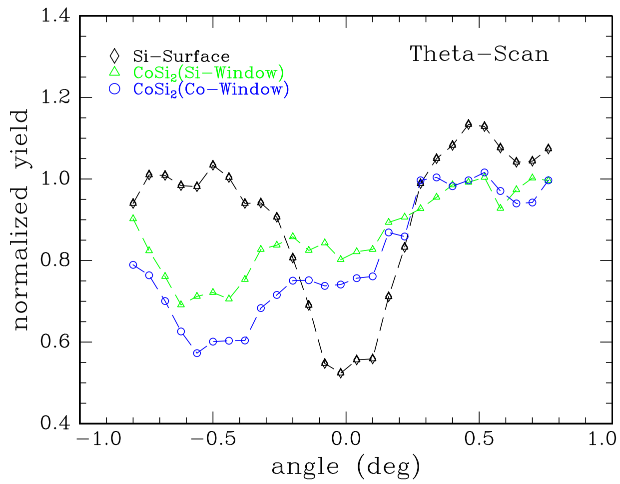

Fig. 2: Channeling angular scans of the $CoSi_2$ sample in fig. 1 through the [111] axis of the Si and $CoSi_2$ layer

An example of channeling-ERDA of a buried $CoSi_2$ layer is shown in fig.,1 and 2 measured with a 150 MeV ^{107}Ag ion beam at a scattering angle of 50.2°. The sample has been prepared by S.Mantl (FZ Jülich) with 200 keV Co implantation and post-annealing. The crystalline quality of the layer structure - Si(100)/$CoSi_2$(70nm)/Si(90nm) - can be seen in fig. 1 in the Si energy spectra at random orientation and aligned to the [111]-axis of the top Si layer and the $CoSi_2$ layer, respectively. The strain between these two layers can be measured with channeling angular scans through the [111]-orientation for the Co and Si component of the buried layer and the surface Si. Due to the small critical angle ψ_c for heavy ion projectiles a second minimum produced by the steering effect at the interface of the strained $CoSi_2$ layer can be resolved. The distance of 0.45°±0.05 between the Si and $CoSi_2$ minimum is a measure of the strain induced angular shift from which a tetragonal strain of -1.67% can be deduced.

References

[1] C.Janicki et al., Nucl. Instr. and Meth. **B34** (1988) 483
[2] W.Assmann et al., Nucl. Instr. and Meth. **B85** (1994) 726