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Double scattering in RBS analysis of PtSi thin films on Si

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Abstract

We present an analytical model for calculation of double scattering in RBS spectra. We show that, in grazing angle of incidence or detection, events with small scattering angle must be taken into account, as long as they lead to paths that are significantly different from the corresponding single scattering event. The effect of lateral spread due to multiple scattering is also taken into account, but in most cases it is not important. We apply the model to thin PtSi films on Si. Excellent results are obtained, except for ultra-thin films measured at extremely grazing angle of incidence, where the analytical model breaks down.

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1. Introduction

All Rutherford backscattering (RBS) analysis codes that implement analytic calculations model single scattering, where the ions of the beam undergo one single large angle scattering event before being detected. Effects such as energy straggling, pulse pileup, or channelling, are taken into account by some codes.

In dual (plural) scattering the ion undergoes two (a few) large angle scattering events before being detected. Multiple scattering refers to the succession of very many small angle scattering events that each ion undergoes. Plural scattering leads to an increase of the yield at low energies, and to a low energy background. Previous analytic double scattering (DS) models [1,2] impose a cut-off angle around 20°, below which it is considered that the trajectories are essentially similar to single scattering, being thus discarded from the DS calculations. These models have been very successful in reproducing experimental spectra of films around 10^2 μm (using a proton beam) or 10^2 nm

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(using a ^{4}He beam) on lighter substrates, measured in near-normal geometry.

This paper is dedicated to the study of double scattering in RBS spectra collected at grazing angle of incidence [3]. We apply the calculations to Pt films nominally 25–200 Å thick on Si. We show that the sharp distinction between large and small angle scattering must be abandoned, leading to a difference in the height of the calculated DS background around one order of magnitude. The influence of lateral spread due to multiple scattering is also calculated, being negligible in these samples.

2. Experimental conditions

Pt films were deposited on Si by electron gun evaporation. The RBS data showed that the films were PtSi. The samples (S10, S25, S50, S100, S200) had nominal Pt thickness (10, 25, 50, 100, 200) Å and determined (3.5, 7.0, 12.5, 24.0, 47.8) 10^{15} Pt/cm^2. RBS was performed with a 1 MeV He^+ beam detected at a 160° scattering angle in the Cornell geometry. The angle of incidence θ between the beam and the sample surface varied between 83° and 4.8°. The beam spot is defined by a rectangular Ta slit system, which was 0.6 mm high, and 0.4 mm wide (except at 4.8°, where it was 0.3 mm wide).

3. Double scattering model

Analytic calculations of RBS spectra are done by dividing the sample in many sublayers assumed homogeneous, of constant stopping power. The beam ions are then followed as they cross the sample, lose energy, and undergo scattering events. To calculate the single scattering spectrum, one single ion path must be followed for scattering at each sublayer. The double scattering spectrum can be calculated using the same methods, but many more trajectories must be considered. For each sublayer, one must consider the first scattering event into the entire solid angle. In practice, one must divide the sphere in a finite number of directions, into which the ion can be scattered (up to 5000, depending on the angle and sample structure). The ion will then suffer a second scattering event, towards the detector.

The Rutherford cross section is not defined for a 0° scattering angle, and usually a minimum limiting angle α_{min} around 15° or 20° is defined, below which the trajectory is considered to be essentially similar to single scattering. Consider, however, trajectories B and SB in Fig. 1. The path length inside the sample before the second scattering is exactly the same. The reasoning above would lead us to discard trajectory B. However, the trajectories are clearly different. Thus, at grazing angle of incidence (or detection) a small angle scattering event can lead to a trajectory which is fundamentally different, and therefore should be taken into account in a double scattering analytic calculation. On the contrary, trajectories A and SA are very similar because the ion has a very short path between the two scattering events. Trajectories C and SC also have similar lengths and paths within each layer, due to near-normal incidence and detection. Hence both A and C should be discarded in a double scattering calculation.

In the algorithm now developed, for trajectories where one of the scattering events has scattering angle smaller than α_{min}, only those trajectories that differ in length from the corresponding single scattering trajectory more than a given factor p_{cutoff} are considered. In this work, we chose a minimum path length change of 50%, corresponding

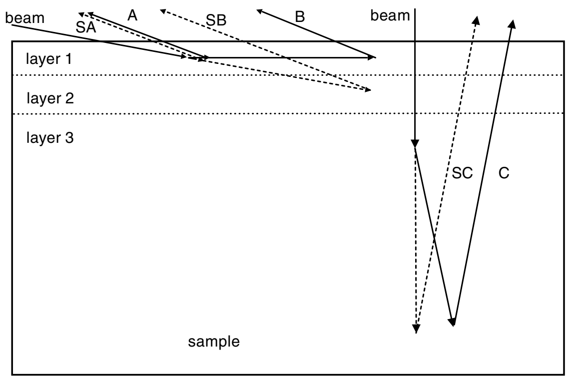

Fig. 1. Schematic representation of double scattering (DS). See the text for more details.